546.42
H224

UNIVERSITY OF ARIZONA
39001007010930

RADIUM

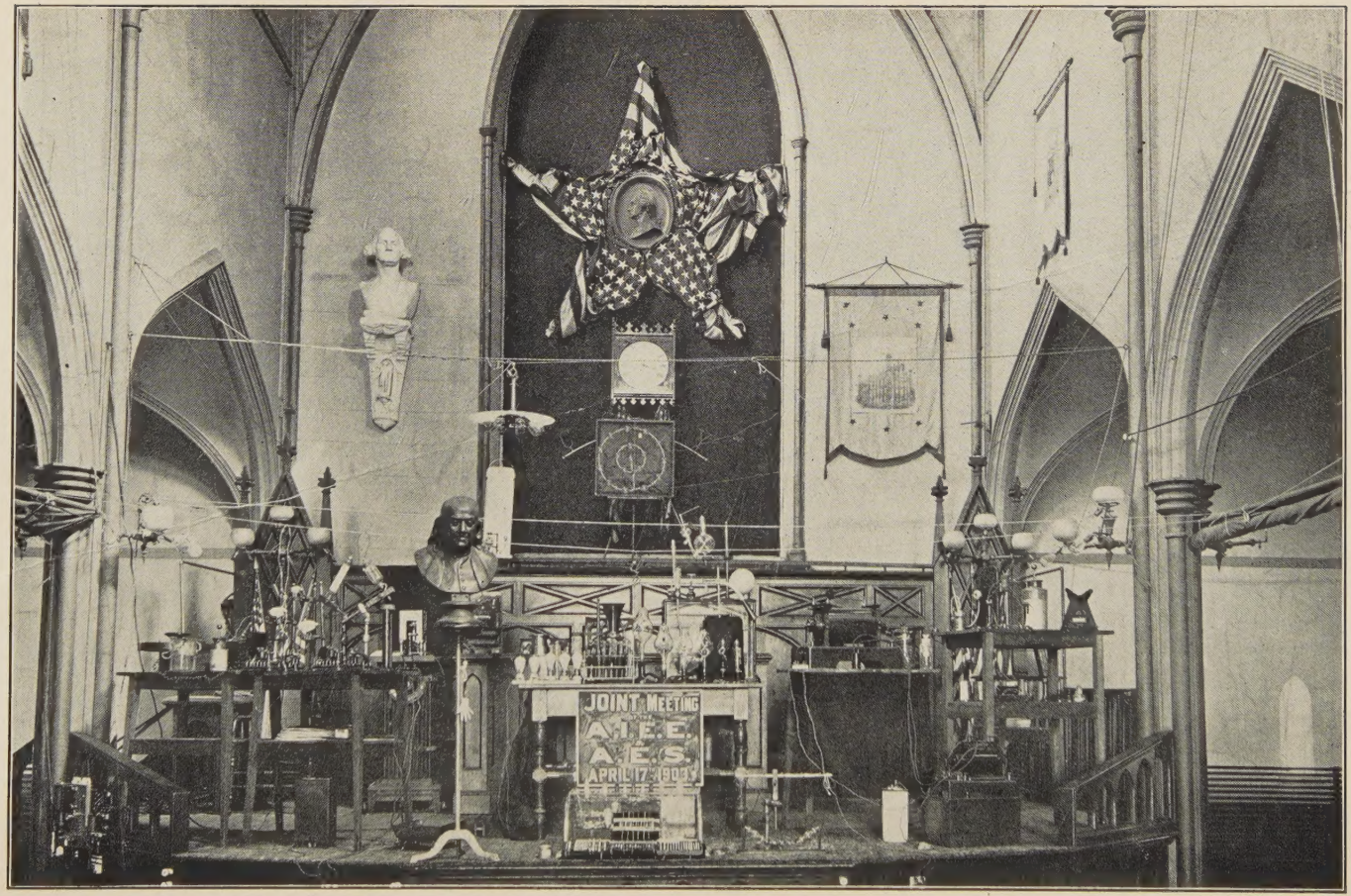
SELENIUM ULTRA-VIOLET LIGHT ETC.

WILLIAM · J · HAMMER.

D. VAN NOSTRAND COMPANY.

Digitized by the Internet Archive
in 2023 with funding from
Kahle/Austin Foundation

https://archive.org/details/radiumseleniumul0000will



Stage Setting in the Chapel of the "College of the City of New York" at the time of William J. Hammer's Lecture before the American Institute of Electrical Engineers and the American Electrochemical Society.

RADIUM,

AND

OTHER RADIO-ACTIVE SUBSTANCES;

POLONIUM, ACTINIUM, AND THORIUM,

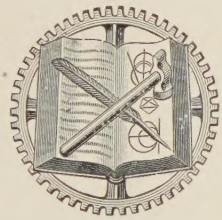
WITH A CONSIDERATION OF

PHOSPHORESCENT AND FLUORESCENT SUBSTANCES, THE PROPERTIES AND APPLICATIONS OF SELENIUM AND THE TREATMENT OF DISEASE BY THE ULTRA-VIOLET LIGHT.

BY

WILLIAM J. HAMMER,

CONSULTING ELECTRICAL ENGINEER.



NEW YORK:
D. VAN NOSTRAND COMPANY.
LONDON:
SAMPSON LOW, MARSTON & COMPANY, LIMITED,
St. Dunstan's House,
Fetter Lane, Fleet Street, E. C.
1903.

Copyright 1903
WILLIAM J. HAMMER.

546.42
H224

CONTENTS.

PAGE

FLUORESCENCE.

What constitutes Fluorescence, Stokes' Law, exceptions thereto, Internal and surface dispersion, Derivation of the word fluorescence, Luminescence, Fluorescent liquids, Fluorescent paintings and writing, Effect of ultra-violet light, fluorescent solids, fluorescent screens, Willemite, Prof. R. W. Wood's ultra-violet screen, The rhodamin screen for the mercury arc..... 1–3

PHOSPHORESCENCE.

Temperatures of red-hot and white-hot bodies, light without sensible heat or flame, derivation of the word Phosphorescence, difference between Phosphorescence and Fluorescence, Bolonese Phosphorus, Canton's Phosphorus, Phosphorescence by insolation, Ways by which phorescence may be stimulated, Luminous Paint, effect of temperature variation, Experiment with bust of Franklin, Phosphorescent signs, stars, philosophical toy showing phases of the moon, wand, postal-cards, etc. Prof. Dewar's experiments, sulphides-of-calcium, barium, strontium, zinc, etc., fluorspar, quinia, fused boracic acid, phosphorescent ether, Cathode rays, Atoms and corpuscles, Phosphorescence in Crookes' tubes, Phosphorescent radiometer, Edison tungstate of calcium lamp. Author's reversal of the Roentgen ray cycle, commercial applications of Phosphorescence, stimulation of phosphorescence by radium rays, Phosphorescence by friction and electrification, Phosphorescent gases, Phosphorescent liquid, Phosphorescence by oxidation or slow combustion, Phosphorescent clouds, snow, insects, fishes, etc., the "Pyrophorus Noctilucus," Phosphorescent flowers, plants, vines, roots, fungi, etc..... 2–11

RADIUM, POLONIUM, ACTINIUM AND THORIUM.

M. Henri Becquerel, the founder of the science of Radio-activity, The phenomena of vacuum tubes, experiments of M. Henry and M. Niewenglowski, Becquerel's remarkable discovery, Uranium, Pitchblende (Uraninite), Polonium and its discovery by M. and Mme. Curie, Discovery of Radium by M. and Mme. Curie and M. Bemont, Discovery of Actinium by Debierne, Crookes' discovery of Uranium X, Radium in liquid air, Lord Kelvin's statement, Radio-active substances, the temperature of Radium, M. and Mme. Curie's hypothesis, Radium a new element, atomic weight of Radium, the standard of Radio-activity, the cost of Radium, Radium chloride and bromide, amount of Radium at present in existence, test of a

7329

diamond's genuineness, French and German Radium products, enormous difficulties met in its preparation, chemical, spectroscopic and electrical analysis, electrometer method of analysis, the Curie electroscope, imparted Radio-activity, Elster and Geitel's experiment, McLennan's experiment, stimulation of Radio-activity, thermo-luminescence experiments of Wiedemann, Thompson, Trowbridge and McLennan, Rutherford's experiments with Thorium, Radio-active gas from Radium, Schmidt's discovery, the physiological effects of Radium, Hidden's theory regarding Radio-active ore, the author's experiment with the "Torpedo Galvani," Faraday's and D'Arsonval's experiments, Prof. Curie's experiments with guinea pigs and mice, the three types of rays emanating from Radium, Deviable "α" rays, "α" rays readily absorbed, they constitute major portion of rays, "β" rays in all respects similar to cathode rays, Tesla's and Blondelot's claims as to deviation and polarization of X-rays, Strutt, Crookes and Rutherford's views as to "α" rays, "γ" rays most penetrative, degrees of penetration of Radium rays, effect of Magnetism on Radium rays, loss of strength of imparted Radio-activity, effect of moisture and high temperature, non-emanating and non-exciting character of Polonium and Uranium, actual deposit of Radio-active matter by Radium and Thorium, Newton's corpuscular theory of light, loss in weight of Radium, views of Profs. J. J. Thomson, Henri Becquerel, Lord Kelvin, Sir William Crookes, P. Curie and A. Heydweiller, coloration of glass by Radium, persistence of Radium rays versus Röntgen rays, opacity of rock salt to Radium and Röntgen rays, illustrations of penetrating character of Radium rays through lenses, lead, steel, black paper, etc., Radiographs of mice made with Radium, showing Röntgen ray effect, Radiograph of the human hand made by Radium, photograph made by phosphorescent sulphide of calcium, Radiograph of same objects made by Radium..... 11–42

THE PROPERTIES AND APPLICATIONS OF SELENIUM.

Variation of resistance of Selenium on exposure to light, discovery of Selenium in 1817 by Berzelius, derivation of the word Selenium, characteristics of Selenium, dangerous character of vapors of Selenium, effects of temperature on Selenium, Willoughby Smith's announcement of May's discovery of effect of light in reducing resistance of Selenium, early investigators into properties of Selenium, Bell's radiophone, Prof. Simon's discovery of speaking arc principle, Duddell's speaking arc, Ruhmer's speaking arc and wireless telephone experiments, theory of phenomena of speaking arc, Hayes' radiophone experiments, resistance of Selenium cells, ratio of resistance in dark and in the light, Shelford Bidwell's invention, method of constructing cells, types of cells, The Bidwell, Ruhmer, Giltay, Webb, Clausen and Bronck, Mercadier and Fritts cells, Ruhmer's latest type of cell, effects of moisture, Giltay's experiments with Radiometer, Ruhmer and Giltay flame telephone transmitters with Selenium cells, author's experiments in firing

cannon, lighting incandescent lamps, starting 3 h.p. motor and generator, ringing bells, operating horn, etc., by shielding a Selenium cell with the hand. Bidwell's experiments and important statement. Thermit and its applications, protection of safes by Selenium cells, Ruhmer's electrically controlled gas buoy, Ruhmer's remarkable Photographophone, employment of Photographophone as a receiver for wireless telephony, seeing at a distance, early experimenters in this art, Crookes' Selenium and chromic acid Radiometer, Prof. Barnard's comet detector, Ruhmer's study of eclipse in a fog with Selenium cell, where Selenium is found, cost of Selenium, Saunder's paper on Selenium. 42–63

THE TREATMENT OF DISEASE BY ULTRA-VIOLET RAYS.

The Finsen Institute at Copenhagen, the deadly character of tuberculosis, Koch's discovery of the "tubercle bacillus," the "Blue Glass Craze," General Pleasanton's book on "Blue and Sunlight," the treatment of smallpox, Finsen's experiments with earthworms and chameleon, the treatment of Lupus Vulgaris by Ultra-Violet light, the aluminum and iron electrode lamps, use of adrenalin chloride for driving blood from diseased parts, use of Röntgen rays for Lupus treatment, Dr. King's experiment, the Finsen blue lens for sunlight treatment, Finsen's telescope tube for use with carbon arc, opacity of blood to Ultra-Violet light, the Finsen pressure glass, method and length of treatment, Finsen's boon to humanity, the founding of the Finsen Institute. 63–72

List of Illustrations.

Frontispiece:	Showing Stage Setting at the time of the author's Lecture.
Fig. 1:	"Pyrophorus Noctilucus."
Portrait:	Prof. Henri Becquerel.
Fig. 2:	Radio-active Substances.
Fig. 3:	Tubes of Polonium and Radium.
Fig. 4:	Apparatus of M. and Mme. Curie for study of Radio-activity.
Fig. 5:	The Curie Electroscope.
Fig. 6:	Radiograph made by Radium of Disc, Rock-salt, and Pitchblende.
Fig. 7:	Radiograph of Lenses made by Radium.
Fig. 8:	Radiograph showing penetration of Radium rays through steel and lead.
Fig. 9:	Radiograph showing penetration of Radium rays through double thickness of black paper.
Fig. 10:	Radiograph of Mouse made by Radium in 24 hours' time.
Fig. 11:	Radiograph of Mouse and Trap made by Radium, showing X-ray characteristics of Radium Rays.
Fig. 12:	Radiograph of Human Hand made by Radium.
Fig. 13:	Photograph of Various Metals, etc., made by Phosphorescent Sulphide of Calcium.
Fig. 14:	Radiograph made by Radium of various Metals, etc.
Fig. 15:	Prof. Bell's Radiophone.
Fig. 16:	Ruhmer's Apparatus for Telephoning over a Beam of Light.
Fig. 17:	Ruhmer's Wireless Telephone operating at night.
Fig. 18:	Types of Selenium Cells.
Fig. 19:	Mercadier's Cell.
Fig. 20:	Manometric Flame Telephone and Selenium Cell.
Fig. 21:	Acetylene Flame Apparatus. Selenium Cell for Operating Electric Lamp, Bell, Motors, Cannon, Horn, etc.
Fig. 22:	Three H.P. Motor and Generator supplying bank of Lamps operated by Selenium Cell, Relay, etc.
Fig. 23:	Compressed Gas Buoy controlled by Selenium Cell, etc.
Fig. 24:	Diagram of Circuits of "Selenium" Buoy Apparatus.
Fig. 25:	Ruhmer's Photographophone.
Fig. 26:	Showing Interior of Ruhmer's Photographophone.

FIG. 27: Mr. Ernest Ruhmer listening to his Photographophone.
FIG. 28: Arrangement of Circuits of Rhumer Photographophone.
FIG. 29: Photograms used in Ruhmer Photographophone.
FIG. 30: Curve made with Selenium Cell during Eclipse.
PORTRAIT: Prof. Niels R. Finsen.
FIG. 31: Main Operating Room, Finsen Institute, Copenhagen.
FIG. 32: Showing Arc Lamp and Finsen Tubes in Operation.
FIG. 33: Lupus Vulgaris Cured by X-rays.
FIG. 34: Finsen's Original Type of Lens Employing Sunlight.
FIG. 35: Finsen's Telescope Tube for use with Carbon Arc Light.
FIG. 36: Showing Arrangement of Arc Lamp and Finsen Tubes.
FIG. 37: Finsen Pressure Lens.
FIG. 38: Showing Lupus Vulgaris Patients before and after treatment with Ultra-Violet Light.

A Lecture delivered at a meeting of the American Institute of Electrical Engineers and the American Electrochemical Society, New York, April 17th, 1903.

RADIUM AND OTHER RADIOACTIVE SUBSTANCES WITH A CONSIDERATION OF PHOSPHORESCENT AND FLUORESCENT SUBSTANCES. THE PROPERTIES AND APPLICATIONS OF SELENIUM AND THE TREATMENT OF DISEASE BY THE ULTRA-VIOLET LIGHT.

BY WILLIAM J. HAMMER.

The author of this paper has endeavored to exemplify certain fundamental principles connected with the phenomena upon which he has treated; and in considering these subjects, all of which may be said to be on the borderland of science, to bring out by means of experiments, lantern slides and illustrations which accompany the paper, the practical and commercial side. He entertains the hope that the matter herewith submitted will prove of interest to the members of the societies before whom he has the honor of appearing, and may serve in some slight degree to stimulate investigations in these most promising fields.

Fluorescence and Phosphorescence.

Sir George Stokes has given the name of "Fluorescence" to the phenomena which certain substances present in altering the very short waves of ultra-violet light, which are invisible, and transforming them into waves of longer length so that they become visible to our eyes.

In electrical parlance a fluorescent substance might be termed a step-down transformer or perhaps more correctly a frequency changer for light waves. Stokes, as a result of his investigations, framed this law, "When the refrangibility of light is changed by fluorescence it is always lowered and never raised"—in other words, the waves emitted during fluorescence are always longer than those which are absorbed, thus causing fluorescence. There are, in fact, cases where the frequency of

the radiations is increased; but where there is such an exception to Stokes' law some sort of chemical reaction occurs.

The lowering of the frequency of certain ultra-violet radiations, so as to render them visible, was known to Brewster in 1833 and Herschel in 1848, the former terming it internal and the latter surface dispersion; but it was first explained and the name given to it by Stokes in 1852, after a form of fluorspar.

In the case of fluorescence, the emission of the light lasts only so long as the substance is stimulated by the incident beam; but in the case of the phosphorescence, the emission of light continues or persists after the stimulation has ceased, or the original source has been removed. The word phosphorescence is from the Greek "phösphoros," meaning light bearer.

Prof. E. Wiedemann has suggested the name "luminescence," to cover fluorescence, phosphorescence and phenomena of that character possessed by many substances whose light emissions are unaccompanied by flame or by the temperature of ordinary light waves; but this term can hardly be made to cover the Becquerel rays emitting from radioactive substances.

I have here to-night a collection of tubes containing fluorescent liquids, such as petroleum, quinine, Magdala red, eosine, uranine, saffronine, paviine, æsculine, amidophthalic acid, fluorescine, rhodamin, etc., all of which show most beautiful changes in color when viewed by direct and transmitted light

I also have some of the fluorescent hydrocarbon "thalleen," prepared by the late Prof. Henry Morton, and some of those most beautiful fluorescent substances, resorcorufin and resorcin blue, for which I am indebted to Dr. Geyer of Steven's Institute. Fluorescent substances are particularly beautiful in the ultra-violet light; for instance: The yellow fluorescene becomes a most beautiful green; the orange colored eosine becomes gamboge; the crimson color of Magdala red a bright scarlet; the straw colored æsculine becomes a pale blue; the transparent and colorless quinine gives its characteristic blue surface tint; the paraffin oil a beautiful blue; and the various other substances giving a beautiful surface color quite different from that of the interior of the solution.

Small pieces of horse-chestnut bark or bark of the ash tree placed in a dilute ammoniacal solution produce a most beautiful fluorescent effect, as the dyeing material descends slowly through the liquid.

Flowers painted with these fluorescent substances on card-

board produce a most beautiful effect when light screened by dark blue or violet glass is thrown upon them.

Sodium vapor fluoresces brilliantly in sunlight.

I also have here samples of tungstate of calcium, platino-barium cyanide, sulphide of zinc, and similar preparations which have been extensively used in the fluorescent screens for X-ray work.

Here is a specimen of Willemite which when exposed to the ultra-violet light produced by the bright snappy condenser spark between these iron electrodes shows a magnificent fluorescence.

Here is a card with words written with a solution of platino-barium cyanide which fluoresces beautifully when exposed to the ultra-violet light of the iron arc, especially when shielded by the accompanying colored glass plates.

I have also one of Prof. R. W. Wood's interesting ultra-violet screens, consisting of four plates of cobalt glass between which are gelatine films containing nitroso-dimethyl-aniline with copper oxide, which screen when employed in front of the arc lamp renders beautifully fluorescent a lump of uranium nitrate held in the focus of the invisible rays.

Through the courtesy of Dr. Von Recklinghausen, I am enabled to show you a Cooper-Hewitt tube which is enclosed in a screen soaked in rhodamin, the best substance which thus far has been found which is fluorescent in the light of the mercury arc.

It is well known that many bodies become red hot at a temperature of between four and five hundred degrees Centigrade, and to make them white hot a temperature of between eight hundred and a thousand degrees is necessary; but there are many substances which are phosphorescent and which possess the property of giving off considerable light without sensible heat.

I have here some samples of two phosphorescent substances which have been known for many years—one of them a sulphide of barium or Bolonese phosphorus, and the other a sulphide of calcium or Canton's phosphorus. The former was discovered in 1602 by Casciarlo, a shoemaker in the city of Bologna who prepared it by the partial calcination of a certain powdered heavy spar mixed with a little flour meal, which he roasted in the furnace; and found afterwards that when exposed to sunlight it would shine in the dark. This preparation was succeeded by the discovery of John Canton, who calcined oyster shells with charcoal and meal in a closed crucible, thus producing a brilliant phosphorescent substance called after his name.

Phosphorescence by insolation—or exposure to sunlight—has been extensively investigated by Prof. A. E. Becquerel and Dr. John W. Draper.

Practically all substances in nature are phosphorescent, and although some of them remain phosphorescent for only one ten-thousandth of a second, others retain their phosphorescence for hours.

One may expose sulphide of calcium to sunlight, and after placing it in a dark room for six weeks it will still affect a photograph plate.

Phosphorescence may be stimulated in many ways—by combustion, pounding, rending, friction, by the vibrations from sources of heat, light or electricity; and these various phosphorescent substances are very susceptible to temperature changes.

Various substances also phosphoresce while undergoing crystallization.

I have here a large sheet of cardboard which has been prepared for me by Messrs. Devoe & Company, which is covered with seven coats of Balmain's Luminous Paint or poly-sulphide of calcium, with perhaps a trace of bismuth and mixed with aerated varnish; and it has been put through hot calender rollers. You will note that this phosphoresces most beautifully when excited by burning this piece of magnesium wire before it, or by focusing the arc light upon it. This phosphorescence soon dies out, however; but upon placing my hand against the sheet, the heat of my hand has caused the card to brilliantly phosphoresce. A cold object placed against the cardboard will very much lessen the phosphorescence at that point.

When I place this bust of Franklin between the arc light and the phosphorescent cardboard, you will note I can thus produce a fine silhouette of that distinguished philosopher.

I have prepared for your consideration a number of objects coated with phosphorescent substances. When I burn this piece of magnesium wire in front of this card, or hold it before the arc light, you will note the initials of the A. I. E. E. and the A. E. S., the two societies before which I have the honor of appearing to-night, shine out brightly. I also have a number of incandescent lamp bulbs, coated internally and externally with phosphorescent substances, which you will note give considerable light when stimulated by the burning magnesium; or by turning on the electricity supplying certain of the lamps.

I remember nearly twenty years ago having cut out tiny stars

from cardboard and painted them with luminous paint, and arranged them on the ceiling of my bed room to represent certain of the principal constellations in the heavens. These stars would absorb the light during the day time, and at night would represent an appearance as though the roof had been removed and one was looking at the stars in the sky.

I have here a philosophical toy which I made years ago, with which I can show the varying phases of the moon. I have taken a 25 cent globe, and painted half of it with black Japan, as representing the dark side of the moon which is never seen, the other half I have painted with a number of coats of luminous paint; and by exciting the phosphorescence of this half by the burning magnesium, you will see that by slowly turning the globe around, a perfect representation of the varying phases of the moon occurs.

I hold in my hand here a long tube coated inside with sulphide of calcium, which makes a beautiful wand, which an orchestra leader might use in a dark scene. I remember years ago fixing up a vacuum tube and coil for use as a baton in the dark scene in Gilbert & Sullivan's Opera of Ruddigore, and fearing lest the complaisant leader be some day knocked off his stool by the 8-inch coil.

Here are a couple of postal cards which I secured in Europe showing the Blue Grotto at Capri. They are printed with phosphorescent paints; and on exposing them to the light, you will see they are exceedingly pretty.

Prof. Dewar has shown that egg shells, feathers, ivory and paper become brilliantly phosphorescent if they are cooled to about 200 degrees below zero by use of liquid air, and then exposed to light. Many bodies seem to possess this power of absorbing energy at low temperatures and giving off light at higher temperatures. In fact, Dewar has observed that at a temperature approximately that of the boiling point of oxygen (184° C.) all bodies, even living tissues, become phosphorescent.

I have here a collection of forty or more glass tubes containing various phosphorescent substances which, when I burn this magnesium before them, you will note become brilliantly phosphorescent, showing red, yellow, green, blue, and in fact, all the colors of the spectrum. The sulphides of calcium, barium, strontium, zinc, etc., largely enter into their composition. I also have here some fine particles of fluorspar, which, when scattered on this hot plate, glisten like fire flies.

A similar effect may be produced by quinia or its sulphate, which when spread on a sheet of paper and laid on a hot metal plate in a dark room, shows a remarkable phosphorescence which develops at the edges and spreads to the centre.

Boracic acid fused and allowed to cool breaks into small pieces, and along the cracks phcsphorescent light appears. Potassium sulphide fused with cream of tartar shows the same phenomenon.

Phosphorescent ether may be prepared by digesting phosphorus in ether for some days in a tightly corked bottle, and when a lump of sugar is dipped into this and dropped into a glass of water, the surface appears quite luminous.

The stream of particles, so thoroughly investigated by Prof. Crookes, was given the name of "Cathode rays" by the Germans, as a protest against Crookes' theory of molecular streams propounded by him at the British Association meeting of 1879; Lord Kelvin has told us that the smallest particle which can be observed by the most powerful microscope contains 18 to 20 million atoms, and although until recently the smallest particle we could conceive of was the atom of hydrogen, this being the lightest of gases, Prof. J. J. Thomson has now shown us that these atoms may constitute a thousand fragments, or as he calls them, "corpuscles," and Crookes showed us, and Villard of Paris recently demonstrated conclusively that the Cathode rays consist of a stream of these hydrogen corpuscles negatively charged and moving at a speed approximating 70,000 miles per second; and as illustrating the complexity of an atom, I am reminded by Prof. Hallock that the late Prof. Henry Rowland once said that a Steinway grand piano was a comparatively simple piece of mechanism compared with an iron atom.

Prof. Crookes has shown many notable experiments in which substances have been caused to phosphoresce inside of the Crookes' tube by the molecular bombardment of "Cathode rays"; and I have here some fine Crookes' tubes containing red and white coral, rubies, calcite, lava, etc., which you will note phosphoresce finely. (I am indebted to Messrs. Queen & Co. for certain of these.)

Prof. Crookes has made a diamond so phosphorescent inside of a Crookes' tube, as to give a full candle power of light. Rubies, emeralds, corals, fluorspar, lime and many other substances similarly phosphoresce in the Crookes' tube.

I have here a Crookes' tube containing calcined sea shells,

which, on connecting to the induction coil, is caused to give off a most brilliant light, and the globe and contents to phosphoresce long after the current is shut off.

Here again I have a tube containing four separately exhausted sections, which are filled with phosphorescent substances, and a tiny tube passing through all of the partitions of the tubes, and being connected with the electrodes at the end. On connecting this to the induction coil a luminous gaseous stream is seen in the tiny tube, and the discharge accompanying it affects powerfully the phosphorescent substances which, you will note, are colored green, yellow, and blue, after the current is shut off.

I have here also a Crookes' "radiometer," the vanes of which are painted with phosphorescent substances, and on connecting the radiometer to the coil the electricity rotates the vanes and causes them to become highly phosphorescent.

At a meeting of the INSTITUTE on January 3, 1902, through the courtesy of Mr. Edison, I was enabled to present some of Mr. Edison's tungstate of calcium lamps which have sometimes been called Edison X-ray lamps. These lamps were Crookes' tubes, the interior walls of which were coated with fused crystals of tungstate of calcium, which were caused to phosphoresce most dazzlingly when they were connected to an induction coil. Through an accident to my large coil, I was unable to show these tubes working as perfectly as I should have liked; and to-night I will show you as an evidence of good faith some of them operating as they should operate, and giving a most powerful light. Incidentally, I am going to show you that this cannot properly be called an X-ray lamp although a form of X-ray tube is employed, as it is not the X-rays outside but the cathode rays inside of the tube which produce the phosphorescence. This tube which I have here and which I have coated with tungstate of calcium and platino-barium-cyanide on the outside, I will now place underneath an ordinary Crookes' tube, that it may be exposed to the X or Roentgen rays; and you will see that while the coated surface fluoresces, as any fluorescent screen will when exposed to Roentgen rays, the moment these rays cease there is absolutely no phosphorescent effect, there being no persistence of the luminescence.

Now, another thing which I think I can show you is that, while cathode rays produce by their action on the interior wall of the glass tube a secondary effect of ether pulsations on the

exterior which are Roentgen or X-rays, I can now produce the converse of this by bombarding the outside of the Edison tube by the Roentgen rays from the Crookes' tube, and you will see then that I have caused cathode rays to be stimulated in the interior of the tube which is merely held near it, causing the tungstate of calcium to become brightly phosphorescent; and you will note that I can deflect the cathode rays with a magnet. I believe this is the first time this conversion of Roentgen rays into cathode rays has been accomplished and is rendered possible by this form of tube.

There are many commercial applications which may be made of this curious property of phosphorescence. Life buoys have been painted that they may be seen when thrown overboard; sheets of cardboard, such as I have shown you, have been used to give light in powder magazines. I have also suggested painting projectiles with luminous paint for use at night; phosphorescent clock and watch dials have been made in large numbers, and it has been suggested to make house numbers, door knobs and escutcheons for key holes of such materials, cover the walls with luminous paper, and even paint the houses with luminous paint.

The taps or keys of incandescent lamp sockets and switches might be made of glass containing phosphorescent material, or the cases painted as I have here done, so that they could readily be seen in the dark; and doubtless certain phosphorescent substances might be used to considerable advantage in connection with various types of vacuum tube lighting and for vacuum tubes used in connection with wireless telegraphy.

I hold in my hand a tiny tube which I secured in Paris, which contains what is perhaps the most brilliant phosphorescent substance that has yet been discovered. It is a special preparation of sulphide of zinc. Here is a second tube containing some of the sulphide of zinc, which also has mixed with it some radium.

A tube of this mixture may be put away in the dark for years, and the radium will act on the zinc, causing it to phosphoresce brilliantly.

Who will say that we shall not some day find a substance which will be so powerfully acted upon by the emanations from radium that it may be used as a source of light?

Here I have a tube which I have made on the suggestion of Prof. Curie, consisting of two bulbs with a stop cock between, in one of which may be placed sulphide of zinc, or similar substances, and in the other radium; and in this manner the radioactivity of various substances may thus be investigated.

A tube containing chloride or bromide of silicon and exhausted to 12 or 15 mm., and sealed, will when rubbed briskly with silk glow in one case a rose color and in the other a greenish yellow.

I hold in my hand here two Geisler tubes, each containing an inner tube with beaded surfaces. In each of the outer tubes is a small amount of quicksilver; and in one tube nitrogen gas, and in the other carbonic acid gas. By shaking these tubes rapidly the friction of the quicksilver against the glass produces electricity, which causes the gas to become luminescent. Various other gases may be thus employed, producing different color effects.

It has been suggested that life buoys could be equipped with a number of mercury tubes, circular or otherwise, and set in different positions, so that the rolling of the buoy in the sea would constantly agitate the mercury and render the tubes luminous.

Here is a tube containing mercurial salts, which changes greatly the color of its phosphorescence by heating the tube in alcohol flame.

In this box I have a large spiral glass tube which is expanded into bulbs at various points throughout its length. This tube, for which I am indebted to my friend Dr. Geyer, contains sulphuric anhydride; and you will note when I connect this to the induction coil and send a discharge of electricity through it that the gas inside of the tube becomes phosphorescent and remains so for a considerable period after the electricity is cut off.

I have here a bottle containing phosphorus and olive oil, which you will see becomes most brilliantly phosphorescent when I withdraw the stopper, and allow the air to enter the bottle. The phosphorescence in this case is due to combustion, or to the oxidation of the liquid. I can also write phosphorescent characters on this ground glass plate wet in hot water with this stick of phosphorus. Other forms of phosphorescence are caused by chemical changes or the slow combustion of decaying vegetable matter or decaying fish.

Occasionally clouds show a phosphorescent light at night; snow is phosphorescent after exposure to sunlight, and no doubt many substances retain during the night the phosphorescent light imparted by the sun's rays during the day.

There are also many insects, such as fire flies and glow worms, and many deep sea fishes which have the properties of producing phosphorescence. Phosphorescence is exhibited among other animals by the infusorian noctiluca, marine radiates, polyps, etc., which are the principal causes of phosphorescence of the sea

In Fig. 1, is shown an illustration of the "Pyrophorus Noctilucus." This tropical beetle has been most carefully studied by Prof. S. P. Langley and F. W. Very, and the efficiency of the light given off tested by the Langley bolometer; and they have demonstrated that practically all the energy which its phosphorescence represents, appears as light; and the light given off by this insect is the most efficient light known, it being produced at about one four-hundredth part of the cost of the energy which is expended in the candle flame*.

Sir Oliver Lodge says if the secret of the firefly were known, a boy turning a crank could furnish sufficient energy to light an entire electric circuit.

And Prof. Langley says, "There seems to be no reason why we are forbidden to hope that we may yet discover a method (since such a one certainly exists and is in use on the small scale)

FIG. 1.—"Pyrophorus Noctilucus" (life size), the Producer of the Cheapest Form of Light Known.

of obtaining an enormously greater result than we now do from our present means of producing light."

Langley believes the light of these insects is due to chemical action, as it is decreased by nitrogen which checks combustion, and is increased by oxygen which increases combustion, and furthermore, the product is apparently carbon dioxide.

We also may produce phosphorescence by rubbing crystals together, or by friction of other bodies, or by cleavage, such as fracture of lump sugar in the dark.

Among plants, phosphorescence was first recorded by A. Linnæus, whose daughter discovered it in the nasturtium. Phosphor-

* "On the Cheapest Form of Light," by S. P. Langley and F. W. Very, No. 1258 Smithsonian Misc. Coll.

escence or flashes of light are often observed, especially just after sunset, in the common red and yellow marigold, the tuberose, sunflower, poke weed, martagon-lily and the poppy. The root stock of khus-khus grass and the sap of certain tropical vines and subterranean plants, some liverworts, ferns, mosses, fungi and algæ, and the mycelium of fungi in decaying wood phosphoresce. This phosphorescence is said to be due to slow decay and oxidation, either in the mycelia or fructifications of the fungi. Heat and dryness soon dissipate it.

Having considered certain of the phenomena of phosphorescence and fluorescence, I wish now to call your attention to these remarkable substances which have recently been discovered, which give off light the moment they are created, without having to be stimulated by any form of heat, light, electrical or other vibrations, so far as we are at present cognizant of, and these substances are attracting a great deal of attention, and are likely to teach us more about the constitution of matter, and the co-relation of the vital and physical forces, than any substances which have been created since the world began. I refer to "Radium, Polonium, Actinium and Thorium."

Radium and Other Radioactive Substances.

Prof. Henri Becquerel.
From a portrait presented to the author.

To the discovery of M. Henri Becquerel, member of the Institute of France, in 1896, of those remarkable radiations emanating from uranium, the science, if we may so term it, of radioactivity, owes its foundation.

Great importance must, however, be attached to the previous investigations into the phenomena produced on the interior and exterior of vacuum tubes of various kinds by such men as Varley, Hittorf, Crookes, Lenard, Roentgen, Hertz, J. J. Thomson, Goldstein, Schmidt, Ebert, Wiechert, Geissler, Kaufmann, Puluj, Perrin, Villard, Wien, Wiedemann, Majorana, Birkland, Deslandres, Poincaré, Edison, Tesla, Rowland, Michelson

E. Thomson, Moore, Rollins, Campbell-Swinton, and others, which investigations had already wrested from Nature so many secrets bearing upon the constitution of matter and paved the way for the Becquerel rays.

Two important links in the chain were supplied by the experiments of M. Henry[1] and M. Niewenglowski[2]. The former showed that phosphorescent sulphide of zinc penetrated black paper and affected a photograph plate, similar to Roentgen rays; and the latter in his experiment replaced the usual cover of a loaded photographic plate holder by a thin sheet of aluminum; on top of this he placed four glass squares sprinkled over with sulphide of calcium rendered phosphorescent by exposure to sunlight. A jeweller's glass bell jar was put over each plate, and the whole apparatus was then placed in a dark room for twenty-three hours. On developing the negative, the plate showed an excellent image of the squares of glass and the bell glass covers which had been made through the aluminum, a substance heretofore supposed to be entirely opaque to light, the white line shown bordering the squares of glass (where the plate had not been affected) indicated that the rays had here been bent or refracted in passing through the edge of the glass, demonstrating that he was only dealing with ordinary light rays.

Subsequently, Prof. Becquerel investigated the effect of phosphorescent substances on photographic plates covered with black paper, such as is used for covering X-ray plates; and which while transparent to X-rays is impervious to ordinary light waves (a plate so protected may be left in the sunlight for twenty-four hours); and he exposed various uranium salts to sunlight to try their effect, at times placing an aluminum, copper or glass plate between the paper and the photograph plate or film. On one occasion after he had placed some double sulphate of uranium and potassium on a photographic plate, the weather became stormy, and he placed his plate with the uranium salts upon it in a drawer, where it remained for several days on account of continuance of the cloudy weather. It then occurred to him to develop the plate; and much to his surprise he found a well-defined impression upon the plate, and this caused without any effect of phosphorescence due to exposure to sunlight. This

1. *Comptes Rendus*, Feb. 10, 1896 Vol. cxxii., p. 312.
2. *Ibid.*, cxxii., p. 386.

led to his discovery and investigation of the remarkable radiations which have since been known by his name*.

I have here some samples of the first substances employed by Becquerel, consisting of double sulphate of uranium and potassium and double sulphate of uranium and ammonium, for which I am indebted to the courtesy of Dr. C. F. Chandler, of Columbia University.

Peligot in 1840 succeeded in isolating metallic uranium from the chloride. Well known forms of it are also uranium arsenate, uranium carbonate, uranium niobate, uranium phosphate, uranium silicate and uranium sulphate. Uranium was first discovered in 1789 by the German chemist Klaproth, he naming it after the planet "Uranus." I have here various forms of this uranium and also some metallic uranium prepared in the electric furnace by Moissan, which is more powerful than any other form of uranium.

Uranium, although widely distributed, is never found in large amounts, and forms several minerals. The commonest of these is "uraninite," commonly known as "pitchblende," which is a compound oxide containing 81½ per cent. of uranium, 4 per cent. of lead and ½ per cent. of iron with oxygen and water, and sometimes magnesia, manganese or silica.

The pitchblende which contains the largest percentage of radioactive material, which has thus far been discovered, is the Bohemian pitchblende. It is also found in Saxony in small pockets, and a distinct vein of it has been found in Cornwall, England. Prof. Curie informed the writer that he had secured some excellent radioactive pitchblende from the United States (Colorado).

The ore as mined in Cornwall yields 18 per cent. to 20 per cent. of the metal, this being the most important source, and this is usually put on the market in the form of uranium sesqui-oxide, and is largely used for giving porcelains a velvety black when heated in the annealing fire, and to some extent for imparting a greenish yellow fluorescence to glass. It has also been suggested to utilize it on account of its high resistance in connection with incandescent lighting.

Following the original discovery of the Becquerel radiations in 1896, came the discovery in 1898 of "Polonium," by Prof. Pierre Curie and Mme. Sklodowska Curie, who in investigating Becquerel

* *Comptes Rendus*, Feb. 24, 1896. Vol. cxxii., p. 420.

radiations from uranium found some samples of pitchblende, from which the uranium is extracted, which was much more powerful than any uranium they had found, being four times the radioactivity of metallic uranium. Concluding naturally that the Becquerel radiations were due to some unknown substance in the pitchblende they commenced a most painstaking search for it, and discovered a substance associated with bismuth, which it resembled very much in its chemical characteristics, to which Mme. Curie gave the name "Polonium," after her native land, Poland.

I have here perhaps the only sample in this country at present of metallic polonium, which in color resembles somewhat the particles of nickel; and here also is some sub-nitrate of polonium.

Where substances are referred to as possessing a certain "radioactivity," for instance 300, it means that the radiations are 300 times as powerful as the original radiations emanating from uranium, which were discovered by Becquerel, and which are taken as a standard of comparison.

The two tubes which I have here to-night are of the sub-nitrate and metallic form, and possess a radioactivity of only about 300. The sub-nitrate form is a white powder, and the metallic, as said, resembles in appearance particles of nickel.

Polonium is precipitated by hydrogen sulphide.

Polonium apparently loses its power much more rapidly than radium; and the Curies have not been able to prepare any in which the rays have been deviable, although Giesel has prepared a form possessing both deviable and non-deviable rays. And Elster states that when polonium is placed in a vacuum, the rays may be deviated by a magnet to a greater extent than those of radium.

Polonium passes more rays through aluminum than do the rays from uranium; but Crookes has shown that they do not penetrate glass, as in the case of radium, and they are readily absorbed by minerals, and readily cut off by thin paper. They are readily absorbed by quartz, fluoride and mica, whereas these substances are freely penetrated by both radium and uranium.

In the same year in which polonium was discovered, those remarkable investigators, M. and Mme. Curie and M. Bemont, succeeded in isolating a second substance found in pitchblende, which was associated with barium and possessed many of the chemical and other characteristics of that substance, and to this they gave the name "Radium." Of this we shall treat later.

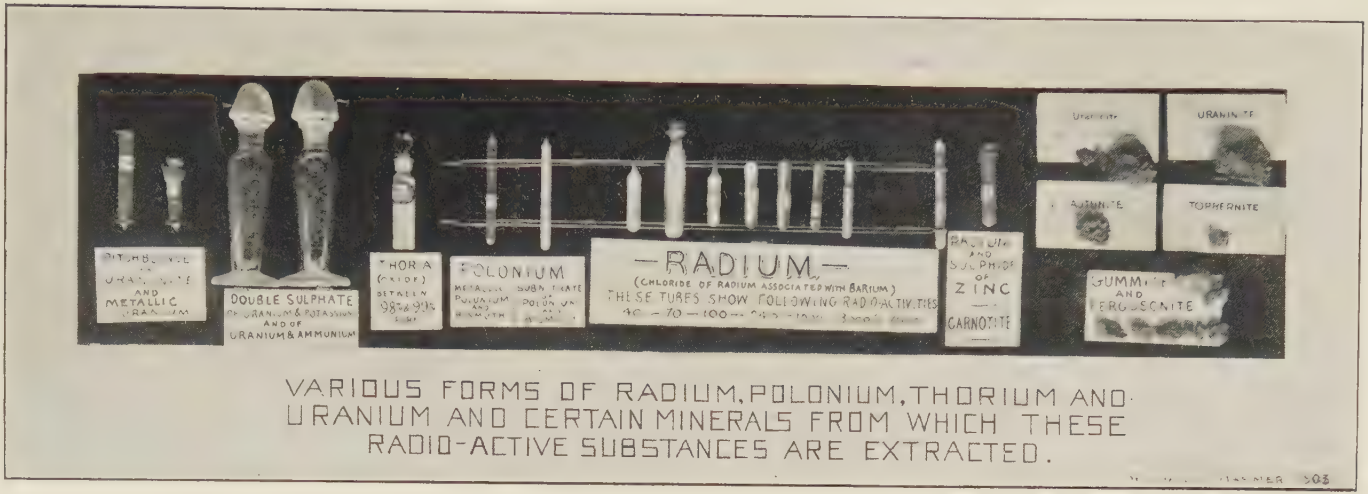


FIG. 2.—Radioactive Substances.

In 1899 was discovered the third substance in pitchblende, which possessed the chemical and other characteristics of thorium with which it was associated, and to this Debierne gave the name "Actinium." It is precipitated by ammonium sulph-hydrate. Crookes states that actinium is identical with the substance which he had isolated from uranium and to which he gave the name "uranium X." The rays from actinium are deviable.

Of the three substances to which I have referred, radium is by far the most important and is of extraordinary interest. It is doubtful whether any substance has been discovered in the history of the world of such stupendous interest and importance and possessing such puzzling characteristics as radium, which seems so at variance with well-established scientific theories as to the constitution of matter.

In Fig. 2 are shown in consecutive order from left to right, a tube containing pitchblende, or uraninite, from which radium, polonium and actinium as well as uranium are extracted; a tube containing metallic uranium made in the electric furnace by Moissan; two flasks containing double sulphate of uranium and potassium; and double sulphate of uranium and ammonium, these being the original salts of uranium with which Becquerel experimented when he discovered the Becquerel rays; a tube containing thorium, the most radioactive substance next to radium; two tubes of polonium and bismuth, one tube of metallic polonium and the other sub-nitrate of polonium; seven tubes of chloride of radium associated with barium ranging in radioactivity from 40 to 7,000; a tube containing radium and phosphorescent sulphide of zinc; and a tube containing carnotite, which, together with the samples shown of uraninite, autunite, torbernite, gummite, and fergusonite, are among the mineral substances which are rich in radioactive materials. Other active minerals are orangite, euxenite, broggerite, cleveite, monazite, samarskite, xenotime, æschynite, niobite, arrhenite, hielmite, sipilite, chalcolite, etc.

In Fig. 3 the two tubes of polonium and the seven tubes of radium are shown about two-thirds their natural size.

Radium, actinium and polonium, Prof. Curie states, possess an activity which is a million times that of uranium. Prof. Curie says radium emits exactly the same quantity of Becquerel rays when in the liquid air as it does at normal temperature of the atmosphere. The luminosity of the chloride of radium is stronger in the liquid air than in the atmosphere at a normal temperature.

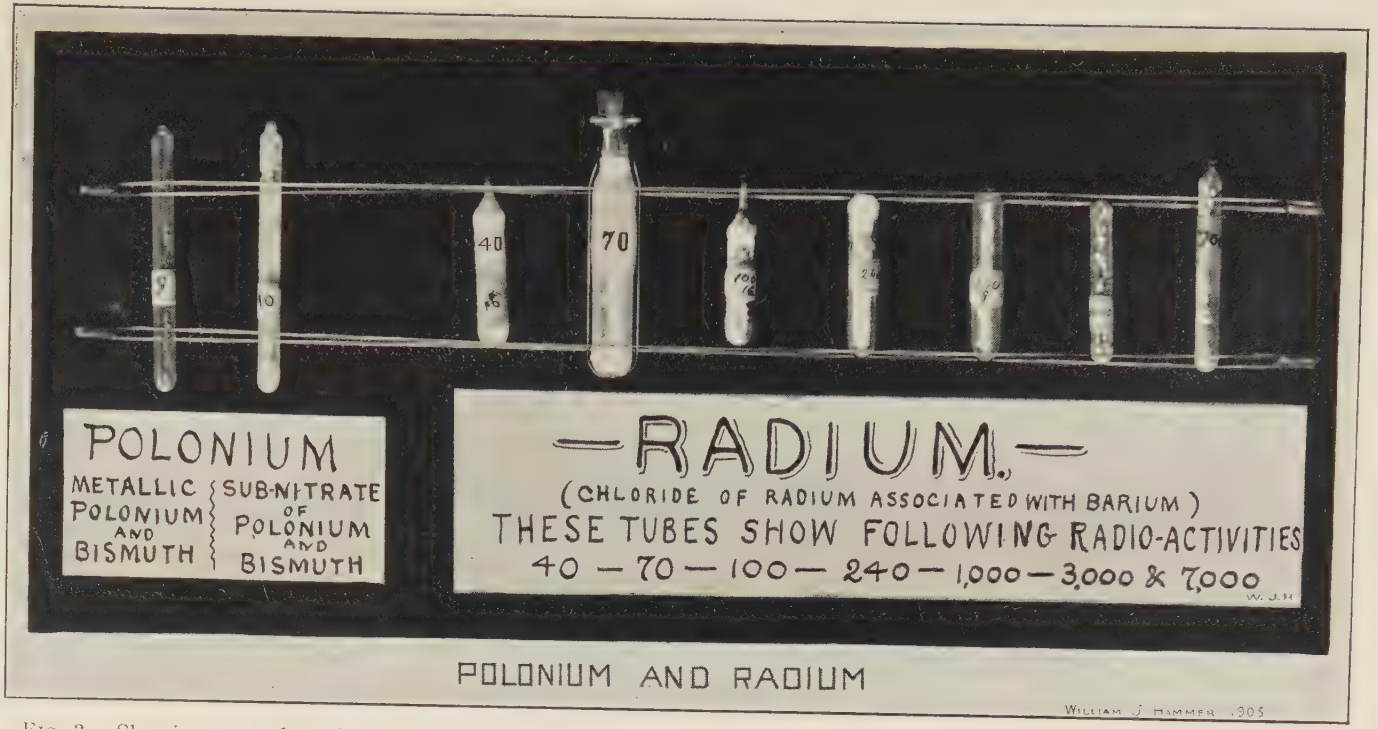

POLONIUM
METALLIC POLONIUM AND BISMUTH
SUB-NITRATE OF POLONIUM AND BISMUTH
—RADIUM.—
(CHLORIDE OF RADIUM ASSOCIATED WITH BARIUM)
THESE TUBES SHOW FOLLOWING RADIO-ACTIVITIES
40 — 70 — 100 — 240 — 1,000 — 3,000 & 7,000
40
70
POLONIUM AND RADIUM
WILLIAM J. HAMMER 1905

FIG. 3.—Showing two tubes of Metallic Polonium and Bismuth and Subnitrate of Polonium and Bismuth, and seven tubes of Chloride of Radium and Barium in the possession of the author. (About two-thirds natural size.)

My friend, Mr. R. R. Bowker, whom I met in Paris last Fall, told the writer that he had shortly before that been dining seated between Lord Kelvin and Prof. Becquerel, and that Lord Kelvin had turned to him and said, that the discovery of Becquerel radiations had placed the first question mark against the principle of conservation of energy which had been placed against it since that principle was enunciated.

Within the past month great interest has been attracted by the statement made by Profs. Curie and Laborde that radium maintains its own temperature at 1.5 Centigrade above its surroundings, this being equivalent to stating that half a pound of radium salt would evolve in one hour sufficient heat to equal that caused by the burning of one-third of a cubic foot of hydrogen gas; and that the heat evolved from pure radium salt is sufficient to melt more than its own weight of ice every hour. This evolution of heat, it is claimed, is going on constantly for indefinite periods and leaving the radium at the end of months of activity as potent as it was at the beginning. The problem therefore confronts the world of solving how radium can constantly throw off heat without combustion or without chemical change, as Prof. Curie says it does.

Messrs. Curie and Laborde employed a thermo-electric couple of iron and constantin, one of whose junctions is surrounded by radioactive barium chloride and the other by pure barium chloride. They used two small bulbs of the same dimensions, one containing one gramme of radiferous barium chloride containing about one-sixth of its weight in radium chloride and the other bulb containing one gramme of pure barium chloride.

The junctions of the thermo-electric couple are respectively placed in the center of each bulb, surrounded by the substances. The bulbs are isolated in air within the center of two small identical enclosures, surrounded in turn by a third, which is thermally insulated, and maintains itself at a practically uniform temperature, and under these conditions variations in the surrounding temperature are felt in the same manner at both junctions and do not affect the indications of the couple. Messrs. Curie and Laborde both thus observed a difference of temperature of 1.5 degrees C. between the radiferous barium chloride and the pure barium chloride, the former having the higher temperature. (*Comptes rendus*, March 16, 1903.)

In a letter recently received by the author from Prof. Curie bearing upon the question of heat given off by radium Prof. Curie writes as follows: "Since the time I had the honor to see

you at our School of Physics and Chemistry I have continued to investigate into the radioactivity induced by radium and the way that radioactivity is disappearing in the course of time.

"In a study of another kind (in collaboration with M. Laborde) I found that the radium is setting off heat continually and in a very large amount; each gramme of the radium is setting off in each hour 100 small calories, or in other words it is setting off heat enough to melt in each hour its own weight in ice.

"Where is the source of this energy? Both Mme. Curie and myself are not able to go beyond some hypothesis; one of these consists in supposing the atoms of radium evolving and transforming into another simple body and despite the extreme slowness of that transformation which cannot be located during a year; the amount of energy involved in that transformation is tremendous.

"The second hypothesis consists in the supposition that radium is capable of capturing and utilizing some radiations of unknown nature which cross the space without our knowledge."

Profs. J. J. Thomson and Rutherford advance the theory that there is a succession of chemical changes going on causing the spontaneous projection of larger masses of material at enormous velocities, and that while certain portions are constantly dying out and becoming inert other portions are constantly increasing in strength and power.

Someone has remarked that for years we have been extracting uranium oxides, and pouring down the waste pipes and into the dust bins the more interesting and precious radioactive substances.

Although radium, polonium and actinium have been termed new elements, in the case of polonium and actinium, they have as yet not been found in sufficiently pure state and in sufficient quantity to give a spectrum, and to prove conclusively that they are new elements. Prof. Curie has, however, stated emphatically that there is now no doubt of radium being a new element.

The tiny brown bulb which I hold in my hand is the duplicate of the one which Prof. Curie showed me at his laboratory last Fall, which contained the only sample of chemically pure radium in the world, this being between two and three one-hundredths of a gramme; and it was the spectrum of that sample, showing only the lines characteristic of radium, as tested by Demarcay, which demonstrated it to be a new element. And with this sample, also, the atomic weight for radium of 225 was determined. The

atomic weight of the barium heretofore always associated with radium, but which in this sample had been eliminated, is but 157.

In answer to my inquiry as to its value, Prof. Curie said that 100,000 francs ($20,000) could not purchase this tiny sample.

I was enabled through the courtesy of Prof. Curie to secure from the Societé Centrale des Produits Chimique of Paris, some nine different preparations of radium and two of polonium, which I have here for your consideration. I was unable to secure any actinium; in fact, but a trace of this substance has thus far been secured.

If the lights are extinguished, and you will sit for a few moments in the dark, I will pass these tubes about the room that you may observe the bright light given off by certain of them. These samples which I have range from forty times the radio-activity of uranium (which is taken as a standard), up to 7,000.

The laboratory, where these substances are prepared, is under the control of Prof. Curie; and up to recent date, all radium of higher radio-activity than 7,000 has been retained for the experiments of M. and Mme. Curie and their associates; but I received a letter recently from Director P. Boulay of the Societé Centrale, in which I was informed that they will shortly put upon the market a preparation of radium, chemically pure or nearly so, at a cost of 30,000 francs ($6,000) per gramme or about $2,721,555.90 per pound.

Radium, while it has been spoken of as a metal, has never been secured in a metallic form, the usual form being as a chloride or bromide.

Prof. Curie told the writer that the result of all the work done in Germany and France in the past three years had only resulted in the securing of about one pound of radium; this including all grades or qualities. Prof. J. J. Thomson says there is far more gold in sea water than there is radium, polonium and actinium in pitchblende.

Prof. Curie took this ring which I have on my hand, which contains a small diamond, into his dark room and holding near it a small pill box containing about a gramme of radium, caused the stone to phosphoresce most beautifully. It was as if a lighted candle had been brought near to it. Prof. Curie remarked that this showed that the stone was a genuine diamond; and if it had been paste there would have been no effect produced, and that radium therefore constituted an excellent means for testing the genuineness of diamonds.

According to M. and Mme. Curie, radium rays act in many ways like light. They reduce silver salts, peroxide of iron and bichromate of potash in presence of organic substances; they also color glass, porcelain and white paper, and they transform greenish yellow platino-cyanide of barium into a brown variety.

Giesel had prepared platino-cyanide of barium with a trace of radium. This spontaneously became brown, and it then polarized light like tourmaline. He also found that this colored rock salt just as cathode rays do, or the vapors of alkaline metals, and furthermore showed that radium salts, brought near the temples or to the closed eyes, produced a sensation of light.

M. Becquerel, referring to the chemical action of radium rays, says that radium and uranium rays act upon silver gelatino-bromide, but produce no effect upon Daguerre plates, or upon photographic papers, and says that colorations of glass, porcelain, paper and certain crystals, as well as the painful physiological effects also belong to this class of phenomena. He also calls attention to the transformation of white into red phosphorus in 24 hours, the reduction of mercuric chloride in the presence of oxalic acid with the precipitation of calomel, and finally the destruction of the germination power of seeds after long exposure.

Becquerel also shows that radium rays possess the same power as the electric spark, or the prolonged action of violet or ultra-violet rays, of restoring the phosphorescent properties under exposure to heat of a body deprived of them by over-heating.

Practically all the radium which has thus far reached this country, with the exception of that in the possession of the author, has been the German radium, and Prof. Curie tells the writer that he had tested all of the German productions, and he has found none of them to exceed a radioactivity of 300.

De Haen of Seelze near Hanover, Germany, and Giesel, of Brunswick, also have manufactured radium. De Haen recently informed the writer that the preparations he puts on the market cost ten and thirty shillings per gramme.

As indicative of the enormous difficulties to be encountered in procuring this wonderful substance, it is interesting to note that it takes 5,000 tons of uranium residues to produce a kilo (2.2 pounds) of radium; and the cost of handling these residues is $2,000 per ton. To secure the chemically pure radium is enormously expensive, and it would be impossible to do this by chemical analysis, therefore the far more sensitive electrical method is employed, and the Curies say that they can detect the presence

of a radioactive substance by the means of such a minute quantity that it would require 5,000 times this amount to show at all in the spectroscope. And it is stated that this method of electrical analysis is thousands of times more sensitive than spectrum analysis and millions of times more sensitive than chemical analysis.

In Fig. 4 is shown the "electrometer" method with which the Curies have studied the radioactivity of different substances. It consists of two plates, A and B, on the latter of which is placed the radioactive substance to be tested. This makes the air a conductor of electricity between the two plates, and for measuring this degree of conductibility, the plate B is brought to a high potential by connecting it to one side of the storage battery P, the

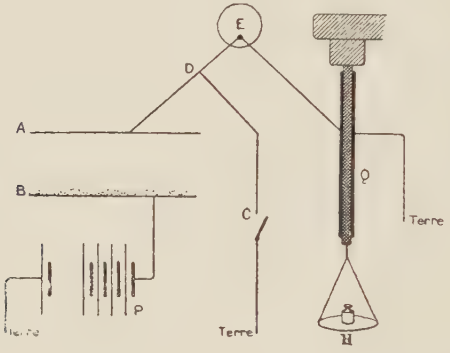


FIG. 4.—Apparatus employed by M. and Mme. Curie in the study of radioactivity.

other side of which is connected to the ground. If the plate A is brought to the potential of the ground by the wire C-D, an electric current begins to flow between the two plates, A and B. The potential of plate A is shown by the electrometer E. If we cut this communication with the ground at C, the plate A becomes charged causing the electrometer to deviate. The speed deviation is proportionate to the intensity of the current and can serve for measuring it. But it is preferable to make this measurement by compensating the charge taken by plate A, so that the electrometer remains at zero. The charges which are extremely feeble can be compensated by means of a Piezo-electric quartz Q,

one armature of which is connected with the plate A, and the other armature grounded. The quartz plate is given a certain tension by weights placed on the plate H. This tension is gradually produced and gives a charge of a definite quantity of electricity which can be measured. The operation may be so regulated that there is a constant compensation between the quantity of electricity which passes through the condenser and that of the opposite sign furnished by the quartz. So we can measure in an absolute value the quantity of electricity passing through the condenser in a certain time.

Doubtless some loss is caused by the rays which pass directly through the condenser plates.

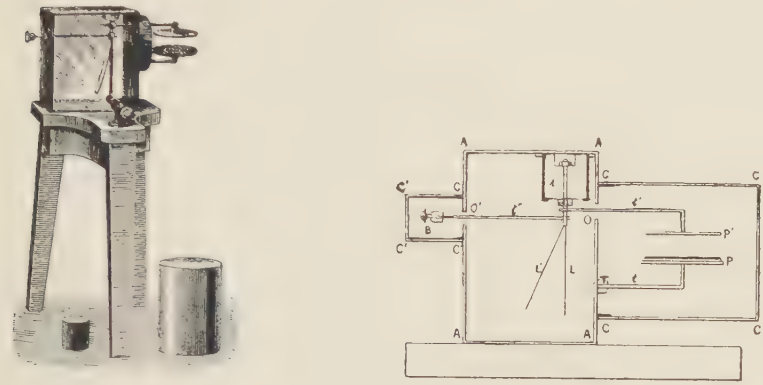


FIG. 5.—Curie's Electroscope for the study of Radio-activity.

Dolezalek has designed a very sensitive type of electrometer built by Bartels of Göttingen, a description of which may be found in *Verk. der Deutsche Physik Ges., iii* (1901).

It is well known that the leaves of a gold or aluminum foil electroscope will hold their charge in dry air indefinitely; but the Becquerel rays are found to dissipate the charge by ionization of the air, or rendering the air a conductor of electricity (the electroscope may also be discharged by Roentgen rays, cathode rays and ultra-violet light).

In Fig. 5 is shown a form of electroscope devised by the Curies for the study of radioactive substances. Referring to the diagram to the right, it will be noted that the electroscope consists of a single movable sheet of gold or aluminum foil attached to a stationary sheet of copper L, being supported by the insulating

piece 1. The radioactive substance to be tested is placed on the lower of the disks P and P′, preferably on a removable plates The radiations make the air a conductor between these two plates. The electroscope is charged by means of a stick of ebonite rubbed briskly and placed near the rod B. This deflects the sheet L′ from the vertical and it so remains for a very long time. When radioactive substances are brought near it, the gold or aluminum leaf is caused to lose its charge, and the leakage is observed by means of a stationary telescope shown in the left hand figure, which is provided with a micrometer scale. The time taken for the discharge of the electroscope is taken by means of a chronometer or watch. By suitable lighting, the front edge of the foil may be made to appear as a very fine line, and its position noted with great precision.

By examining the diagram it will be noted that the upper condenser plate is connected with the metallic case. Detachable metal cases are placed over the condenser plates and over the rod for charging the electroscope. Two of the sides of the case are of glass.

I have here a simple form of electroscope with leaves of aluminum foil, which serves to show the ionization of the air; when the radium is brought near the divergent leaves lose their charge of negative electricity and rapidly come together.

It is of paramount importance that the radioactive substance should be kept in a room distant from the electroscope.

At the present moment the clothes of every person in this room and all the walls of the room are radioactive by reason of the presence of the nine preparations of radium which I have here this evening.

Prof. Curie told the writer that it was often impossible for him to go near his instruments to make any measurements for hours, after being in the proximity of some radium, and those who have worked with this substance have found the greatest difficulty in keeping their tools and instruments and themselves free from the radioactivity imparted by the radium. The energy represented by radium is something enormous.

Elster and Geitel* have shown that a fine wire of any metal placed in the atmosphere and charged negatively from some source of current, say of 500 volts, causes the wire itself to become radioactive, and this radioactivity may be scraped off

* *Phys. Zeit.*, 1901, ii., p. 590.

and will affect photograph plates, ionize the air, etc. It cannot, however, be washed off. It is stated that lightning rods and even the leaves of trees all become radioactive, and it has been shown that falling rain and snow are for a time quite powerfully radioactive; and after they have fallen, a wire negatively electrified in the atmosphere has only a small amount of radioactivity, apparently showing that the rain and snow have carried the radioactive particles in the atmosphere down to the ground.

McLennan has made experiments with the negatively charged wire in Montreal and subsequently at the foot of Niagara Falls; and has found the result about one-sixth as powerful in the latter place as in the former; and he has also shown that it was not necessary to electrify the wire used at Niagara Falls, as it received a sufficient charge from the electricity in the atmosphere.

McLennan found that rain caught in a vessel and immediately evaporated to dryness imparted radioactivity to the vessel in which it was evaporated.

Ordinary water when evaporated and rain water which has stood for several hours before being boiled down do not yield any radioactivity.

As an evidence of radioactivity imparted to another substance by radium, I have here some pieces of cardboard which constituted the box which held my samples of radium for several months. The box becoming injured, I broke it up, fortunately saving the pieces; and six days after the radium had been removed, I looked up the pieces and was surprised to find them luminous in the dark. Subsequently I tried their effect on a photograph plate; but did not succeed in getting any impression. Three weeks later it occurred to me to try and stimulate the radioactivity of the cardboard, which had not been near radium for over a month, by burning magnesium wire, when I found I could make the cardboard brighter than it had been in the first place. I have also stimulated the radioactivity by sparks from a coil, especially when producing ultra-violet rays, by using a condenser bridged across the secondary and employing pure iron electrodes. I tried the burning magnesium with various samples of cardboard which had not been exposed to the radium, and there was no phosphorescence. It has already been stated that various substances which become radioactive retain that property for a short time only, and it is interesting to note its retention for such a long period of time and to note this

ability to stimulate and make visible the imparted radioactivity.

This experiment suggests the discovery made by Prof. E. Wiedemann that a mixture of sulphide of calcium with a little sulphate of manganese is not altered when exposed to cathode rays; but some time after its exposure it bursts into a vivid greenish glow when slightly heated; and to this phenomenon he has given the name "thermo-luminescence."

Prof. S. P. Thompson also showed that fluorspar, which by prolonged heating has lost its luminescing power, regains the power of thermo-luminescence on exposure to Roentgen rays when reheated.

Prof. Trowbridge also finds that this restoration is also effected by exposure to the electric glow discharge, but not by exposure to ultra-violet light.

It is also stated that an object coated with calcium sulphide and exposed to the sunlight will phosphoresce about ten hours; and even after it has lost its luminosity, it can be caused to again give light by heating first by the hand, then over a water bath, and finally on a hot stove.

McLennan has found a very large number of salts are brought into a condition by cathode rays, in which warming makes them radioactive for a short time, the supply of negatively charged particles discharged from the surface coming to an end.

Prof. Rutherford of Montreal, who has given a great deal of attention to radioactive substances, particularly to investigations into thorium, which next to radium is the most radioactive substance yet discovered, has found that by electrifying a wire negatively with a current of 500 volts connecting the positive pole to the ground, and by connecting a sample of thorium to the earth, that the thorium particles were attracted to the negatively charged wire, producing a greater radioactivity than he had ever found in any thorium preparation which he had made.

I have here a sample of oxide of thorium, the radioactivity of which was discovered independently by Schmidt and Curie. This sample is between 98 and 99 per cent. purity. From this body Prof. Rutherford has isolated a substance which he calls "ThX;" and extraordinary as it may seem, it has been found after separation of the active constituents represented by the ThX from the thorium, that the ThX loses its radioactivity, and this is taken up by the thorium in exactly the amount which the other loses.

Sir William Crookes has also separated a non-uranium residue

from uranium, leaving the latter without radioactivity. Whilst the whole of the radioactivity has been concentrated in the residue to which the name UrX was given, Crookes, as already stated, claims that Actinium is but another name for his UrX.

The only case of radioactivity induced by cathode rays in a neutral substance has been that of bismuth, discovered by Villari.

Prof. Curie has discovered that radioactive gas emanates from radium, and Rutherford has discovered the gaseous emanations from thorium, Messrs. Rutherford and Soddy have investigated extensively these emanations, and they have succeeded in condensing them at the temperature of liquid air. A preliminary account appears in the proceedings of the Chemical Society of London for December, and Prof. Rutherford writes me that the full paper will shortly appear in the Philosophical Magazine; and he states furthermore that in his opinion this proves beyond doubt the gaseous nature of the emanations.

The serious physiological effects of radium are well known, and Messrs. Giesel, Becquerel, the Curies and others have given important evidence thereof. As stated in the appendix of a paper read by the writer at the 159th meeting of the INSTITUTE on January 3, 1902, dealing with the subject of radioactivity, Prof. Curie told the writer that he would not care to trust himself in a room with a kilo of pure radium, as it would burn all the skin off his body, destroy his eyesight and probably kill him. The writer felt the effects for weeks of a slight burn from inadvertently carrying a wooden box containing eight tiny sealed glass tubes of radium under his arm for several hours.

Mr. W. E. Hidden has called the attention of the writer to some phenomena which he has observed in a mine in Barringer's Hill, Llano County, Texas, which mine contains yttrium, thorium and uranium. Pockets of ore have been found, ranging from a few ounces up to a capacity of 70 kilos, which were the nuclei or focal points of rigid lines radiating in every possible direction. These lines penetrating great masses of quartz and orthoclase feldspar, and gigantic pegmatyte, to distance often of several feet, in some cases of from five to eight feet, he has observed that these radial lines were fissures and bore no relation to the natural cleavage or the crystalline form of the huge rock masses in which they existed. Easy parting took place along these radial lines, making the ore quickly available.

It is Mr. Hidden's theory that, as these lines directed to ores

rich in uranium and thorium, both well known sources of radium, etc., the phenomenon is due to an electric or other effect of radioactivity; it being untenable, he believes, to explain this phenomenon on the basis of expansion or contraction.

The slide which I will show on the screen shows clearly a pocket of ore with the lines radiating therefrom in all directions.

Eighteen years ago, while in Italy, the author visited the celebrated aquarium in Naples, which is probaby the finest in the world; and while there was enabled to test the shocking abilities of the Electric Ray, or "Torpedo Galvani," and was astonished at the tremendous shock which he received; and in this connection, it is interesting to call attention to the fact that there are fifty or more fishes which are known to possess this property of giving powerful shocks. The "Gymnotus" or Electric Eel, and the "Torpedo Galvani" or Electric Ray being the best known of these.

It will be recollected that Faraday drew a powerful spark from a Gymnotus at the Polytechnicum, London, and he estimated the shock to be equivalent to that given by a battery of Leyden jars of 3,500 square inches of surface. And many writers have referred to the ability of these electric fishes to give powerful shock for a long period of time. D'Arsonval has caused them to light incandescent lamps and they have been known to magnetize needles and decompose water by the electricity they produce. These fishes doubtless using this faculty as a means of defence and also for procuring food. My object in mentioning this is to state that last Fall I again visited Naples and thinking that perhaps an electric torpedo was on exhibition, it occurred to me to take with me some half dozen tubes of radium which I had in my bag, and see whether the radium had any effect upon the power of the fish to give powerful shocks. The fish, as at the time of my previous visit, was lying in a shallow wooden box containing wet sand and a small amount of water. By taking hold of the side of the fish and pressing with the thumb on one side and the fingers on the other, or by either pinching or tapping the fish, the cells with which the fish was equipped discharged themselves and gave a shock sufficient to twist one's arm very badly. After the members of our party had each received a shock, and as soon as a few persons present had gone away, I laid the six tubes of radium on the fish (which is shaped very much like a flounder), leaving them there for about twenty minutes. I then replaced the tubes in the box, and taking hold

of the fish tried for fifteen minutes to get it to give me a shock by tapping or pinching in the same manner as previously done when the fish gave off shocks, and without receiving the slightest shock. Now, I am prepared to admit that the fish might have been "entirely out of shocks"; still, it is well known that these fishes will continue to give out shocks for a very long period of time, one authority reporting 360 shocks in seven minutes' time; but after exposing the fish to the radium, I could get absolutely no manifestation; and in this connection, it is to be remembered that the physiological effects of radium, such as burning, destroying microbic life, producing the sensation of light when a tube is held against the closed eye or temples (which is doubtless largely due to the phosphorescence of the pupil of the eye, but which may also affect the nerve centers), and also the electrical effects, where charged bodies are caused to give off their charge by the ionization of the air; and one must also remember the very numerous chemical effects and the destruction of the germinating power of seeds, the changing of oxygen into ozone, and various other phenomena of radium which would lead one to wonder whether the radium did not affect the ability of the fish to give off electric shocks, perhaps producing a partial paralysis.

The experiment is of some interest, and may be perhaps repeated by others who have better facilities than I to continue the investigation. I have sometimes wondered how that fish was getting along in Naples; though I believe the waters of the Mediterranean abound in them.

Note—Since writing the above description of his own experiments, the writer has learned of the recent experiments conducted by Prof. Curie, in which a few milligrams of radium introduced beneath the skin of a mouse near the vertebral column produced death by paralysis in three hours; and tubes of radium placed in contact with the back of the necks of guinea pigs have killed or paralyzed these animals in a few hours, according to the length of exposure to its fatal radiations.

As illustrating the action of radium rays upon bacteria, E. Aschkinass and W. Caspari speak of exposing cultures of *Micrococcus prodigiosus* to a radium preparation, and state that the rays killed the germs very effectively in about three hours.

The work of Rutherford, the Curies, Becquerel, and others has demonstrated that there are three entirely distinct types of rays emanating from radium (Rutherford having first pointed out that uranium possessed two separate types of rays, "α" and "β"

the former easily absorbed even by gases, whilst the latter are very penetrating and but little absorbed by gas). Those which constitute by far the most important class are the "α" rays. They constitute the major proportion of the rays, and are those which produce the greatest portion of the ionization of the gas, which has been observed under experimental conditions.

These "α" rays possess in common certain characteristics of Roentgen rays, and by many have been thought to be Roentgen rays. I shall call your attention later to certain effects which are identical with those produced by Roentgen or X-rays. They have been considered absolutely non-deviable, as X-rays have been held to be.

Rutherford has, however, recently shown that in a very powerful magnetic field he could deflect about 30 per cent. of the rays, and in experiments now being conducted with a strong electric field, he has been able to deflect about 45 per cent. of the "α" rays. The "α" rays are readily absorbed, and a thin screen of metal will serve to cut off the greater portion of them.

In this connection I would state that Mr. Tesla informed the writer recently of an experiment he had made in which he had succeeded in deflecting the X-rays themselves, and M. Blondelot has recently claimed as the result of his experiments that X-rays are susceptible of polarization. If this is so, it is argued they may be shown to be ordinary light waves of extremely short wave length.

Strutt and Crookes have suggested that the "α" rays consist of positively electrified particles, and this view Rutherford supports, calling attention to the fact that they possess characteristics similar to the "Canal Strahlen" of Goldstein. These Goldstein rays have been shown by Wien to be positively charged particles, moving at high velocities.

Rutherford, as a result of his most recent observations, considers that the "α" rays move at much higher velocity than the Goldstein rays; and he estimates that the energy of the "α" rays is a thousand times greater than that of the "β" rays.

Rutherford says all the radioactive substances, including polonium, as well as excited bodies and the emanations, give out "α" rays.

The "β" rays are much more penetrative and much longer, and in every particular correspond to the characteristics of cathode rays. They are readily deflected by a magnet. They

discharge electrified bodies by ionization of the air, affect photograph plates, etc.

M. Villard, in 1899, proved that the cathode rays are negatively electrified corpuscles or fragments of atomic hydrogen, and these corpuscles, as they were named by J. J. Thomson, which he has shown to be one one-thousandth of the mass of the hydrogen atom, are projected from the cathode at a speed approximating 70,000 miles per second.

The "γ" rays are the rays possessing the greatest penetrative effect. They will excite or produce radicactivity through the air at a distance of three or four feet or more.

Some recent experiments made by Rutherford show the relative penetration of the three classes of rays through aluminum sheets of varying thicknesses, before a loss is observed of half of the intensity, and this shows for the

"α" rays a thickness of aluminum of .0005 cm.
"β" rays a thickness of aluminum of .05 cm.
"γ" rays a thickness of aluminum of 8. cm.

Mr. Rutherford, who has conducted most painstaking investigations into the penetrative character of the radiations from uranium, radium, thorium, etc., recently wrote the author in answer to some questions on the subject, that he had found that the radium rays were reduced to half value after passing through 1 cm. of lead, 1 inch of iron and about 8 inches of water, the radiation being reduced to about 1 per cent. of its original value, after passing through 7 cm. of lead, 7 inches of iron and 56 inches of water.

In the lantern slide thrown on the screen is an interesting illustration of the effect of magnetism on the deflectable rays from radium. There are four large steel magnets, two being placed opposed to each other, and the other two so that unlike poles are opposite to each other, making a strong field of force between the two magnets. I have placed six tubes of radium a short distance above the magnets and in a line running across and between the poles of the two pairs of magnets. It will be seen that the magnetic rays in the case of one pair of magnets have repelled the radium rays so that the negative is but slightly affected. Whereas, in the case of the other pair of magnets the radium rays have been attracted by the magnets affecting considerably the negative around the pole pieces.

Prof. Curie states that half of the induced radioactivity, when exposed to the air, is lost in certain substances in half an hour;

but in a closed vessel, where the air has been made radioactive, however, this radioactivity has not lost half of its strength, even after four days' time.

It is desirable to keep radium free from moisture, preferably in sealed glass tubes. It readily takes up moisture, and then soon loses its luminosity, which may, however, be regained by dissolving and precipitating the substance and thoroughly drying it. The luminosity may also be considerably heightened by subjecting the radium to high temperatures.

Polonium like uranium does not possess the power of exciting radioactivity, as it does not give off any emanations; whereas, in the case of radium and thorium, there is an actual emanation, producing radioactivity in surrounding objects by the deposit of radioactive matter.

When one considers the remarkable effects produced by radium it would almost seem that it is matter tearing itself into tiny pieces, and projecting these infinitesimally small particles through all matter at a speed from half to even the full speed of light, and rendering all substances about it radioactive, and still without appreciable loss in weight in the original substance, and without disparagement of the accepted wave theory of light one naturally "harks back" to Newton's corpuscular theory of light.

While various theories have been advanced to account for the phenomena of radium, there remain many things which have not been satisfactorily accounted for; and perhaps the subject which has been most widely discussed is the loss in weight of radioactive substances.

At the British Association meeting last summer, Prof. J. J. Thomson is reported to have stated that if a square centimeter of surface were covered with pure radium, it would only lose in weight one thousandth of a milligram in a million years. This is in accordance with the previous statements made by Becquerel.

Later in the year, A. Heydweiller, of the Royal University, Munster, Germany, stated that he had been testing a sample of De Haën's preparation of radium, and found that it lost in weight two one-hundredths of a milligram per day for fifty days, and a whole milligram in that period. (*Phys. Zeit.*, Oct. 15, 1902.)

The great discrepancy in the statements on this important subject led the writer to enter into correspondence with Profs. J. J. Thomson, Henri Becquerel, Lord Kelvin, Sir William Crookes, P. Curie and A. Heydweiller, which resulted in the following expression of view.

Prof. Thomson was inclined to think that from the magnitude of loss found by Heydweiller, it must be due to some secondary effect, and he stated that he could not speak with certainty without a greater knowledge of the details of the experiments. As accounting for the results he, however, drew attention to the well-known coloration of glass by radium, by remarking, "One point, however, that ought to be attended to in these experiments is the effect of the radiation from radium on glass. Glass, as is well known, gets deeply colored when in contact with radium. It seems to me possible that the glass might be charged right through. If this were the case, it is possible that reactions might occur between the glass and the air, producing volatile substances and a loss of weight. I only throw this out with hesitation, for as I said before, I am not familiar with the details of the experiments."

Prof. Becquerel informed the writer that he knew nothing reliable regarding the experiments of Heydweiller, and called attention to his original paper on this subject which appeared in the *Comptes rendus* of March 26, 1900, adding, "I believe I am the first to have published an estimate in this way which could only result from my own experiments. The loss of one milligram per square centimeter requires one thousand million years. This statement refers only to the part of the deviable portion of the radiation to which measurements were applied; but this is only a part of the total loss. The deviable radiations comprise rays ranging from 10^9 and 3.10^{10} c.m. Besides, there is also all the non-deviable portion, either penetrating or absorbing, which corresponds to a notable loss of energy; and in addition, if the emanation is of material importance, which seems quite probable, the loss on this account would be a thousand times greater. These estimates are but theoretical, for it is probable that at least a portion of the mass calculated or estimated as material is apparent and corresponds to the effects of induction."

In response to an expression of view from Sir William Crookes on a theory to satisfactorily account for the phenomena of radioactive substances, he wrote as follows: "You will find them fully given in my address to the British Association at their Bristol meeting in 1898. I have not seen any special reason to alter the views there propounded"; and in writing on the subject of Heydweiller's experiments, Prof. Crookes says, "I do not think the experiments of Heydweiller have been corroborated by other observers; and there are many sources of error in his

experiments which I should like to see discussed before giving credence to it. Personally, I find no loss of weight in a rich sample of radium compound during continuous weighings extending over many months. I should be inclined to agree with Becquerel and J. J. Thomson."

Lord Kelvin wrote that he was sorry not to have been able to make any experiments on radioactive substances which could allow him to offer any opinion that would be helpful on the subject, and added, "What you tell me regarding radium and your correspondence with Prof. J. J. Thomson is very interesting."

On this point Prof. Curie recently wrote me as follows: "I never did believe in the exactness of Mr. Heydweiller's experiments; and I always thought he did not take care enough to avoid some source of errors. In fact, with a substance considerably stronger than his own I only obtained a reduction in weight of 1-10 of a milligram in four months for several decigrams of substance, and as the tubes were used at the same time in several experiments, that loss of weight does not allow me to affirm that radium is losing weight spontaneously. I believe, meanwhile, as does Mr. Heydweiller, that the question cannot be answered in any other than an experimental way, and that all speculative theories are of small interest. I have published my recent researches in the *Comptes Rendus de l'Académie des Sciences de Paris.*"

As regards the published statements of Prof. Heydweiller's experiments, the writer can state that he is most reliably informed that a mishap occurred during his experiments which resulted in one of the tubes becoming cracked, which was not observed until later; and that this practically nullified the results published; and, in fact, they have not been confirmed by subsequent tests; but, on the other hand, they tend to corroborate the experiments of Becquerel and the statements made by him, Sir William Crookes, J. J. Thomson and others. The writer is also informed that Prof. Heydweiller is continuing further experiments, the results of which will doubtless be published when his investigations are complete.

As bearing upon the coloration of glass already referred to, I hold in my hand a flask which I secured at the laboratory in Paris which has contained radium, and has been most beautifully colored a deep violet. I also have several tubes in which radium has been kept, which are similarly colored, and in this connection I would call attention to the fact that X-ray tubes which have

been in use for a considerable time become similarly colored, forming another link between the Roentgen rays and radium rays.

I also have here a tiny bulb of glass which is colored a deep brown. I have seen only one other piece of glass colored in this way, this being due to the difference in the chemical constituents of the glass (though in some cases the glass subsequently turns a violet color). This is a duplicate of the tiny tube which Prof. Curie showed the writer, which contained between two and three one-hundredths of a gramme of chemically pure radium.

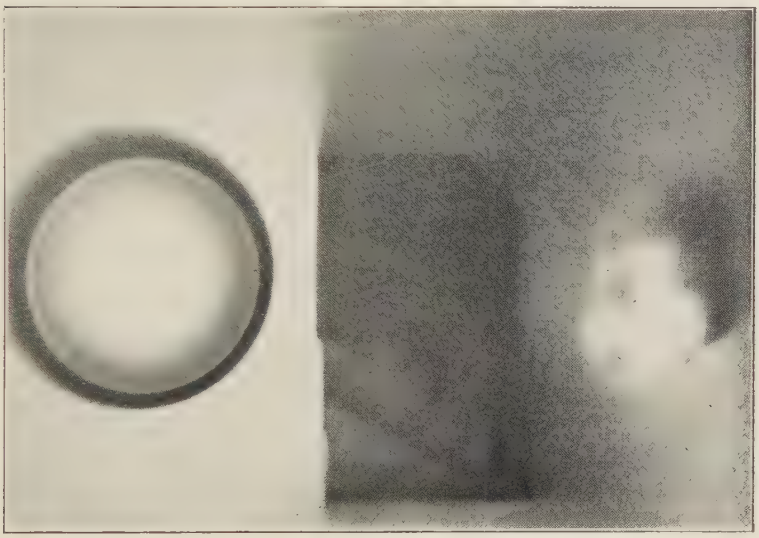


FIG. 6.—Radiograph Made by Radium of a Disk for Testing Radioactivity, a Block of Rock-salt and a Lump of Pitch-blende.

It is interesting to note that the Becquerel rays induce activity which persists, whereas that excited by Roentgen rays ceases immediately on the removal of the rays.

As illustrating the X-ray character of radium rays I would call your attention to Fig. 6, in the center of which is shown a block of rock salt. The original sample was about one inch thick, and was so transparent that a person's features might be seen through it. The rock salt is not only transparent to ordinary light, but also to ultra-violet light, whereas it is very opaque to X-rays.

Mrs. Hammer, appreciating the serious physiological effects of radium, has made the interesting suggestion that radium be kept in boxes made of rock salt; and the author is now having such a receptacle made. This might be even more satisfactory than a lead box. It would be interesting to note the change in the temperature of such a box or vial which so well intercepts the Radium rays.

The illustration referred to was made by placing the rock salt on a photograph plate with the radium some 5 inches above it.

To the right of the rock salt is shown a piece of uraninite (pitchblende), from which radium is extracted; and you will note that not only has the mineral been photographed by the radium above it, but the radium has acted on the radioactive constituents of the pitchblende and caused this to affect the plate.

The disk shown at the left of the cut is one made in Paris for the examination of radioactive substances. I have one of these here, and it consists of a rim of brass, enclosing a brass washer with a glass disk at the center. The opposite face is covered with aluminum foil, and between the aluminum and the glass is placed some radium of 1,000 radioactivity. Substances which it is desired to examine are laid on this disk. It is, however, a rather crude piece of apparatus; but in the cut shown not only has the disk been photographed by the radium 5 inches above it, but the radium inside of the disk has penetrated through the aluminum and fogged the plate.

In Fig. 7 are shown some interesting effects of the radium rays in affecting a photograph negative after passing through lenses. The lenses "A" and "B" are plano-convex condensing lenses, one being placed with the flat surface down, and the other with the convex surface down. "C" is a double convex lens of crystal, "D" is a plano-convex lens of uranium glass and "E" represents an ordinary glass prism.

It is stated that radium rays cannot be reflected, refracted or polarized. Those familiar with the phenomena of light will, I feel sure, be interested in the above photograph.

In Fig. 8 is shown another illustration of the penetrative character of the rays, it being a thick lead box containing six tubes of radium, ranging from a radioactivity of 40 to 7,000; this box being laid upon a large steel magnet $\frac{3}{8}$ of an inch thick. You will note the degree of penetration of both the lead and the steel varies according to the radioactivity of the radium in the various tubes. The exposure was made in twenty-two hours.

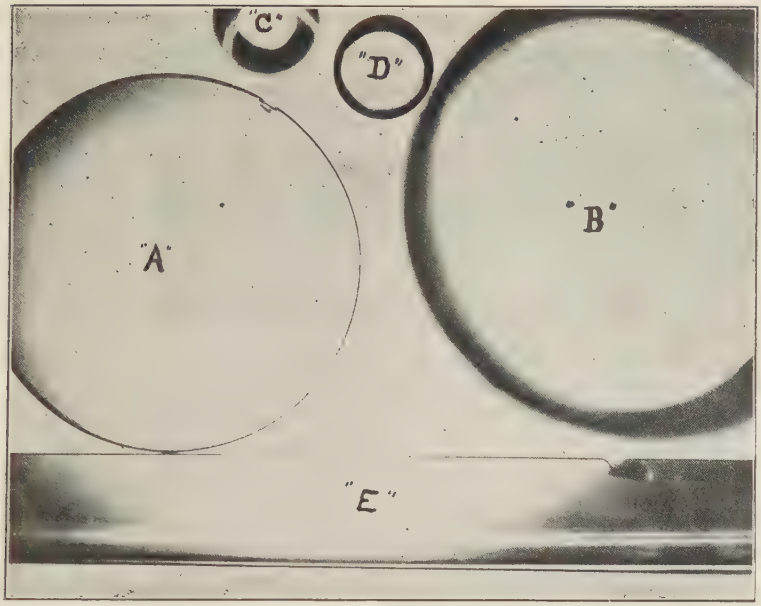


FIG. 7.—Radiographs of Various Types of Lenses Made by Radium.

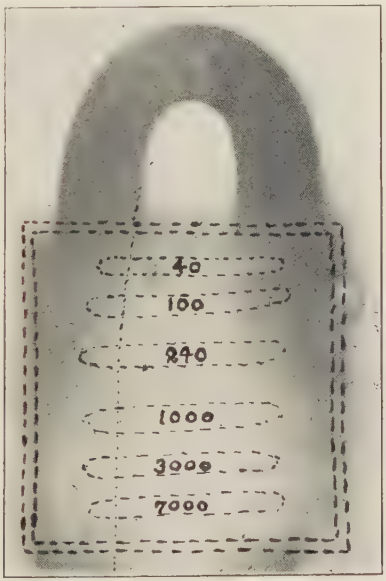


FIG. 8.—Radiograph showing Degrees of Penetration of a thick sheet of Lead and a Steel Magnet by Tubes of Radium of Different Radioactivities

Fig. 9 illustrates the penetration of the rays through black paper, the steel tool shown having been laid on the plate covered with two thicknesses of heavy black paper, such as used for

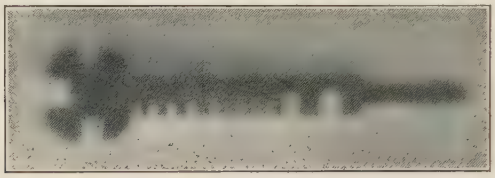


FIG. 9.—Radiograph of Steel Tool Made by Radium Acting Through Two Thick X-ray Plate Envelopes.

wrapping X-ray plates; a single sheet of which is entirely impervious to light. The exposure was made in twenty-four hours.

Fig. 10 shows a mouse which was radiographed in twenty-four hours by laying it directly on a plate, which was, as in the case of

FIG. 10.—Radiograph of a Mouse Made by Radium in Twenty-four Hours.

other experiments, placed in the bottom of a trunk, the trays being replaced and the trunk wrapped in three thick rugs, and kept in a dark room for twenty-four hours.

The radiograph of the mouse shown in Fig. 11 represents a mouse caught on another occasion, in which I placed the mouse, trap and all on the plate, leaving it there for three days. The trap was an ordinary 6 cent trap; and it will be noted that the metal parts of the trap are shown opaque, whereas the portion of the wood nearest to the radium is shown absolutely transparent, as if it had been exposed to X-rays. In the original photograph

the mouse is also shown somewhat transparent, indicating slightly the bones.

I also show you in Fig. 12 and upon the screen a slide which I have made of a radiograph of a human hand. This was exposed for eight days, and bears resemblance to an X-ray picture which has been overexposed. In making a faint print of this, a slight trace of the bone is shown and the embalming material employed is brought out strongly. This is, perhaps, the first picture made of the human hand by means of radium; and it would not have been possible, of course, to have exposed a living person to these rays for even a small percentage of this length

FIG. 11.—Radiograph of Mouse Caught in Trap and Exposed to Tube of Radium for Three Days. (Note Transparency of Wood, as with X-rays.)

of time. Perhaps subsequent experiments will bring out much more strongly the bone structure (the irregularity in the fingers is due to their being somewhat cramped).

As X-rays will excite phosphorescence in many substances, one would naturally wonder whether there were any X-ray characteristics in phosphorescent substances.

An interesting experiment is shown in Figs. 13 and 14. In the former experiment, I have placed strips of various metals, such as brass, iron, copper, tin, lead, tinfoil, aluminum, platinum, magnesium, etc. and strips of carbon, vulcanite, glass, mica and celluloid.

FIG. 12.—Radiograph of a human hand made by Radium in 8 days' time.

FIG. 13.—Photograph Made by Phosphorescent Sulphide of Calcium of Iron, Brass, Copper, Tin, Lead, Aluminum, Platinum, Tinfoil, Magnesium, Carbon, Glass, Mica, Celluloid, Vulcanite, etc., and Strip of Black Paper. (See Fig. 14.)

Across the middle of the plate I have placed a strip of thick black paper cut from an X-ray plate envelope. I then sprinkled over the entire plate by means of a sieve sulphide of calcium, which I had made brilliantly phosphorescent by exposure to burning magnesium ribbon. The only substances which allowed the light to pass through at all were the glass, mica and celluloid, the other substances, including the paper, being very opaque, showing apparently only the presence of ordinary light rays. This plate was placed for twenty-four hours in a dark room.

FIG. 14.—Radiograph Made by Radium of Same Substances as in Fig. 9. Note Black Paper is Transparent, as are Certain of the Other Substances, especially those directly below the Radium.

In Fig. 14 are shown some substances similarly arranged, but exposed to a tiny tube of radium of 7,000 radioactivity, which was placed 3 inches above the plate and near the center. The exposure was made for twenty-five hours; and it will be noted that the strip of black paper has entirely disappeared, and the various substances underneath it have been penetrated to a greater or less degree; particularly, those nearest to the radium.

A bibliography of "Radio-Activity," even at this early date,

would be very extensive; among the publications containing the most important contributions are *The Phil. Mag., Comptes Rendus, Ann. der Physik, Revue Gen. des Sciences, Nature, Jour. de Phys., Soc. Francaise, Phys. Bulletin, Chem. News, Phys. Ges. Verk., Phys. Zeit, Science Abstracts, Wied. Ann., Proc. Royal Soc., etc.*

The Properties and Applications of Selenium.

The extraordinary property which selenium possesses of varying its electrical resistance on exposure to light is a phenomenon which has been known for a long time; but the commercial applications of this peculiar property possessed by selenium have not been properly appreciated up to the present time.

It is my purpose to invite your attention this evening to a number of applications of selenium which the writer believes will prove of no small interest to the electrical engineering profession and perhaps stimulate investigations in this most promising field.

The Swedish scientist, Berzelius, discovered selenium in 1817, as a by-product from the distillation of sulphuric acid from iron pyrites. The proximity of the earth and moon suggested to Berzelius the name "Selenium" after the Greek "selene" (moon); this being the result also of the striking similarity of the properties of selenium with those of tellurium, which is a term derived from the Latin "Tellus," (earth). Its atomic weight is 79.5; specific gravity when crystallized, 4.788; its observed vapor specific gravity at 2588° F. 5.68. It is a non-metallic element, which possesses characteristics similar to phosphorus, sulphur and tellurium. When melted at 212° Centigrade and allowed to cool rapidly, it forms a brown amorphous mass of conchoidal fracture. In this condition it is a high class insulator. It has been said that a small piece of it would represent the resistance of a wire stretched from the earth to the sun. When heated for quite a time at a temperature of 100° Centigrade, selenium becomes a conductor of electricity to a limited degree, this increasing with an increase of current and varying according to the direction. Selenium has neither taste nor smell.

The red vapor rising from selenium when subject to intense heat is exceedingly poisonous, and care should therefore be taken when experimenting with selenium in liquid form.

Selenium is usually supplied commercially in a vitreous form. Here are some samples of it, and you will note that it is as structureless as glass and resembles black sealing wax. I also

have here some amorphous selenium in which form it is a finely divided brick red powder. This changes into vitreous selenium when exposed to a temperature of from 80° to 100° Centigrade. In order to obtain crystalline selenium, in which form it is useful for selenium cells, it must be kept as already stated at from 100° to 200° Centigrade for some time, the black mass being changed into a hard slate-colored metallic looking substance. In this form even the thinnest films are opaque to light, whereas in the vitreous form the film would be transparent and ruby red in color. I have some of these films here for your examination.

Selenium is to-day employed to a considerable extent for the coloration of glass.

In 1851 Hittorf first discovered the effects of temperature on selenium; but it was not until February 12, 1873, that Mr. Willoughby Smith sent a communication to President Latimer Clark, of the Society of Telegraph Engineers of London, calling attention to the effect of light in reducing the resistance of selenium. An assistant of Mr. Willoughby Smith, a Mr. May, who was a telegraph clerk at Valencia, called attention to the fact that some pencils of selenium which had been used to give a high resistance in connection with some of the cable testing work conducted by Mr. Willoughby Smith, showed a marked change in resistance when the sliding cover of the box which held the selenium was removed, and the selenium was exposed to sunlight. These selenium pencils varied in length from 5 to 10 centimeters, and were 1 to 1½ mm. in diameter; they were hermetically sealed in glass tubes with connecting wires of platinum at each end. Little credence was given to the original announcement; and it was only after Earl Ross verified this statement, and proved that the action was due solely to light, and showed the effects of the light of different portions of the spectrum, that it met with serious consideration. Since that time much work has been done investigating the properties of selenium, especially by Messrs. Shelford Bidwell, J. W. Giltay, Lord Ross and Sale, Draper and Moss, Hittorf, Adams and Day, Ayrton and Perry, Sir W. C. Siemens, Werner Siemens, Mercadier, Fritts, Minchin, Ruhmer, Webb, Bell and Tainter, and many others.

Alexander Graham Bell some twenty years ago made some interesting experiments with his radiophone, a diagram of which is shown in Fig. 15, in which a mica or glass diaphragm covered with a silvered foil was used to reflect a powerful beam of light upon a selenium cell placed in the focus of a silvered reflector.

To the selenium cell were connected a pair of telephones and a battery. At the back of the silvered diaphragm was a flexible tube and mouth piece into which words were spoken. The sound waves causing the diaphragm to vibrate sent pulsations of the reflected light upon the selenium cell, producing corresponding variations in its resistance and reproducing audible sounds in the telephone. Prof. Bell only used this over very short distances.

In 18 8 Prof. H. T. Simon of the University of Göttingen discovered that an arc lamp, the circuit of which was in proximity to a telephone circuit, was caused to vibrate very perceptibly and he devised his interesting speaking arc by means of which he superimposed the sound waves produced by the telephone upon the circuit in which the arc was placed. He connected the lamp circuit with the secondary winding of an induction coil,

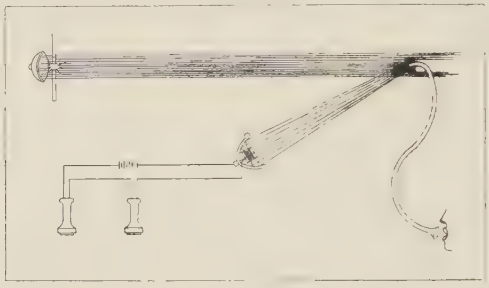


FIG. 15.—Prof. Bell's Radiophone.

the primary circuit being connected with the carbon transmitter, and a battery. The sounds thus produced originally were very weak; but by employing a suitable carbon microphone, the sound was reproduced to large audiences.

Conversely, the arc could also be used in conjunction with telephone receivers to receive sounds.

It is also found that the transmitter battery may be omitted, and a shunt taken from the arc circuit may be used with the transmitter and a suitable resistance. Again, this resistance may be displaced by storage batteries; and in this case to secure the most satisfactory results, self-induction ("reaction coils") should be placed in the circuit of the arc lamp, allowing the direct current to pass without obstruction; but offering extremely high resistance to the alternating currents produced by the carbon transmitter. By compensating in this way any disadvantage in the use of the shunt is done away with.

The transmitter may also be placed in shunt with the reaction coil instead of in shunt connection with the arc lamp, and this has the advantage that the rheostat used with the storage batteries may be omitted, provided the windings of the reaction coil are suitable for use as a resistance. By this arrangement, the lack of self-induction in the transmitter circuit permits of a very clear and distinct reproduction, sufficient to be heard by large audiences.

Mr. W. Duddell, of England, has made some most successful talking arcs, which the writer had the privilege of seeing in London over two years ago. In his arrangement in the secondary circuit is placed a condenser, which prevents the lamp current entering the induction coil; but allows the induction current in the transmitter circuit to pass without obstruction; and this arrangement has the effect of greatly increasing the sound. By employing a condenser of from three to five microfarads, he compensates for the difference of phase produced by the self-induction in the circuit, thus producing the highest effect in the arc.

When Duddell uses the arc for transmitting sound waves, he employs in the shunt circuit to the arc a condenser and receiving telephone. It is advisable to employ as long an arc as possible. It has also been found that the Moore vacuum tube and the various types of mercury arc, such as Arons, Hewitt and Weintraub, are very suitable for this class of work, as well as the carbon arc; and where the latter is employed, either cored or treated carbons are advisable.

The theory advanced to account for the phenomena of the speaking arc, is that variations in temperature of the arc are produced by the variations of the current, and the change in the Joule effect produces a corresponding variation in the volume of the conductive gases in the arc.

The most successful and most extensive experiments which have been made with the speaking arc are those of Mr. Ernest Ruhmer, of Berlin, Germany, who has employed it in conjunction with his selenium cells for wireless telephony and with remarkable success. In Fig. 16 is shown the apparatus employed by Mr. Ruhmer, with which he has succeeded in transmitting speech over a beam of light 4¼ miles in length.* Mr. Ruhmer's apparatus is shown in the illustrations thrown upon the screen,

* Mr. Ruhmer has recently written the author that he has succeeded in talking over a beam of light a distance of over ten miles.

and in Fig. 17. In his experiments he employed an arc lamp with a flaring arc 6 to 10 mm. long, using an e.m.f. of 220 volts. The current varied from 4 to 5 amperes at 1 to 2 k.m., 8 to 10 amperes for 3 to 4 k.m., and 12 to 16 amperes for 5 to 7 k.m., and the resistance of his selenium cell was 120,000 ohms in the dark, this falling to 600 ohms in full sunlight. For the transmitting end, Mr. Ruhmer employs a carbon transmitter and a battery superimposing waves on the arc light circuit; and the beam of light is reflected to some distant point, where it is received by a parabolic reflector, in the focus of which is placed a selenium cell connected with a battery and a pair of very sensitive telephone receivers.

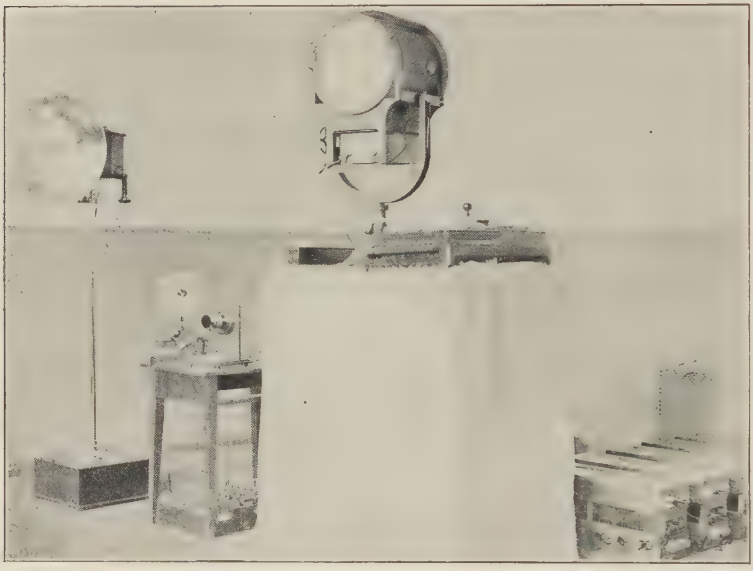


FIG. 16.—Ruhmer's Apparatus for Long Distance Telephony over a Beam of Light.

Mr. Ruhmer has conducted extensive experiments both by night and by day, and even during fog and rain on the Wannsee, near Berlin. On the screen you will see an illustration of his apparatus in actual work at night. (Fig. 17.)

Some time ago I suggested to Mr. Ruhmer the employment of Edison's tasimeter, the extraordinary sensitiveness of which is well known. He informed me that he had tried this; but had found it too "lazy"; and stated that he has secured most promising results by the employment of the thermopile; and with this he expects to be able to transmit sound over many miles.

Mr. Ruhmer is about to commence extensive experiments under the direction of the German Government in connection with the Imperial fleet in the Baltic Sea.

Mr. Ruhmer has also suggested the employment of his photographophone, which I shall describe later, as a means of recording messages received at a distance.

Doubtless many present remember the interesting experiments made by Mr. Hayes at the Electrical Exhibition held in Madison Square Garden in May, 1899, in which music was transmitted over a beam of light. At one end of the Garden was placed a telephone, before which a cornet was played, causing waves of

FIG. 17.—Ruhmer's Wireless Telephone Receiving Station at Wannsee, Berlin (taken at night).

current in the telephone circuit to be superimposed upon those in a neighboring arc light circuit. The light rays from this arc lamp were reflected across the Garden, where they were received in a parabolic reflector in the focus of which was a glass bulb containing filaments of carbon. This bulb was connected to a pair of ordinary phonograph listening tubes. The varying light which fell upon the carbon caused variations of temperature inside of the glass bulb which produced the original sounds in the listener's ear. A bulb simply coated with lamp black and containing nothing but air, would answer the purpose just as well.

Selenium cells may vary in resistance from 2,000 ohms to 500,000 ohms or more in the dark; and certain cells may be five

to twenty times as good conductors of electricity in light as in the dark; and in the case of other cells, notably that of the Fritts cell, which I have here this evening, and that of the Ruhmer cell used in his Wannsee experiments, will have two hundred times the conductivity in light that it has in the darkness; and the ratio may be even higher.' They are usually made by winding carefully two separate lengths of wire, either of copper, brass, German silver or platinum, equidistant throughout their entire length upon such substances as slate, glass, mica or porcelain. The selenium is then spread thinly over the wires, forming an insulation between the two windings. This form of cell was invented by Mr. Shelford Bidwell, F. R. S. No small amount of skill is necessary to wind these fine wires evenly and equidistant, and to cover successfully these wires with the selenium coating. One way of coating frequently employed is to warm the cell on a metal plate or sand bath heated by a Bunsen burner. When the stick of selenium laid on the plate shows evidence of melting, which takes place at about 120° Centigrade, it is drawn slowly over the wires, coating the same thinly and evenly. A steel spatula or a strip of mica can be used with advantage.

Or the strip of material on which the wires have been wound would be laid upon a brass plate covered by a strip of this mica, this being placed upon a tripod with a Bunsen burner underneath. Powdered vitreous selenium may thus be spread evenly over the wires, and the selenium will shortly melt, and where the portions of it crystallize, forming hard lumps, it will be necessary to continue the heating until these disappear. Then the selenium may be spread uniformly with a piece of steel, or better still, a strip of mica, care being taken to cover up the edges. Mr. Bidwell states that the temperature should be carefully regulated, as when it is too low hard crystalline lumps will form, and when too high the surface tension causes the selenium to form in drops, and it is then as difficult to spread as if it were mercury. The proper temperature should be only just above 217° Centigrade; and then the selenium is in a plastic semi-fluid condition and can be easily manipulated. When a satisfactory surface is secured, the cell should be placed upon a thick copper plate to cool quickly, when the selenium becomes black and lustrous. The Bunsen flame should then be turned down to give a temperature of about 120°, and the cell is then placed upon the hot plate; and shortly, the whole surface of these turns to a dull gray color. The temperature is then cautiously raised until signs of melting begin to

appear, generally near one of the edges. When this occurs, the burner is instantly withdrawn and the flame lowered. The dark spot recrystallizes in the course of a few seconds, and the burner is then replaced and left for four or five hours, during which time the Se should be only a few degrees below the melting point. The coil should then be gradually cooled by lowering the flame gradually for an hour. This process of long heating and slow cooling is generally spoken of as "annealing."

In Fig. 18 is shown an illustration of a number of types of selenium cells, including the Bidwell, Ruhmer, Giltay, Webb,

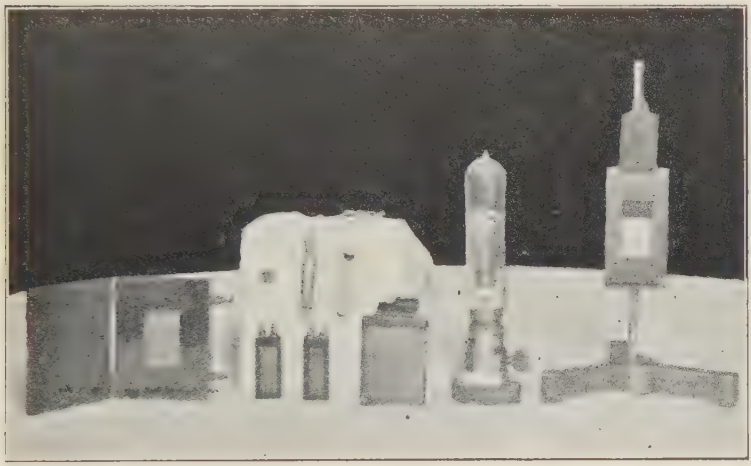


FIG. 18.—Types of Selenium Cells.

Clausen and Bronck, Mercadier and Fritts, which I have brought with me for your consideration.

The two cells to the extreme right and left are modifications of Mr. Shelford Bidwell's cells, the original form of which consisted of two fine copper wires wound side by side on oblong strips of mica with melted selenium spread over the surface, the one to the left being manufactured by Ernest Ruhmer, of Berlin, and by Messrs. Clausen and Bronck, which consists of copper wire wound on slate. The one to the right is manufactured by Mr. J. W. Giltay, of Delft, Holland, and consists of platinum wire wound on slate and covered with selenium. The four tiny cells shown against the white background are made by Mr. Hartwell W.

Webb, of New York City, and consist of German silver wire wound on slate. The cell to the right is placed in a sealed flat glass tube. The two lower Webb cells are incased in ebonite. The small round cell is a tiny Mercadier cell made by Mr. Webb. The method of making the Mercadier cell is to use two narrow ribbons of sheet brass or foil, separated by a ribbon of parchment paper rolled up like a spiral spring. This is held between wooden clamps, one surface being ground and polished off smoothly, and a thin layer of selenium being spread over it. An excellent idea of this cell may be had by noting Fig. 19, which shows the standard form.

In the center of the picture is shown a cell of Mr. C. E. Fritts, of New York City, for which I am indebted to my friend Prof. Geo. F. Barker. In the Fritts cell a very thin layer of selenium from one one-thousandth to one five-thousandth of an inch

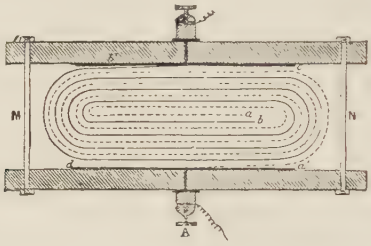


FIG. 19.—Mercadier's cell (block and dotted lines represent the two ribbons of brass).

in thickness is spread upon a plate of metal, generally zinc or brass. The selenium and metal plate form a chemical combination sufficient at least to cause the selenium to adhere and make good electrical connection. The upper surface of the selenium is then covered by a transparent conductor of electricity, preferably a thin film of gold leaf. Platinum or silver may also be employed. Thus the two surfaces of the selenium are covered by a metal and are connected to the two ends of the circuit. The upper or gold leaf surface, however, permits the light to pass through and affect the resistance of the selenium beneath.

The tall cell in the lamp socket shown is the latest form of Mr. Ruhmer's cell, and this type represents, I believe, the most important development which has been made in the selenium cell, and it has now become most stable and responds most rapidly to variations in illumination. He employs two copper wires,

wound spirally side by side around a cylinder of porcelain, which, after the wires have been covered with selenium, is placed inside of a globe, from which the air is exhausted, and it is mounted with a butt similar to an Edison incandescent lamp, and resembles a candelabra lamp. This makes a most convenient method of handling the cell; and by keeping it from the air the disadvantages inherent in all cells heretofore have been very largely done away with.

Another form of Ruhmer cell consists of two fine platinum wires wound on a glass cylinder $1\frac{1}{4}$ inches long and $\frac{3}{4}$ of an inch in diameter; the wires which are 1/32 of an inch apart are coated with selenium.

Selenium cells are very susceptible to moisture, and it is largely this taking up of moisture which produces the electrolytic effect in the cell, enabling one to connect it with a galvanometer and produce a current by merely focusing the light upon the cell. This phenomenon gave rise to the designation of the photo-electric cell.

Those who have worked with selenium cells know that heretofore they have been most unreliable; varying their resistances from time to time enormously; and in the case where copper wires are employed, there is a selenide of copper formed, which often renders the cells inoperative in a comparatively short time.

To some extent, the cells made originally have been protected by covering them with mica or lacquer or varnish; but placing them in an exhausted receptacle and mounting them in the manner devised by Mr. Ruhmer is, it seems to the writer, a most important step in the commercial development of the selenium cell.

Prof. Bell has made a number of types of selenium cells, his standard form consisting of alternate disks of brass and mica, with the mica disks slightly smaller than the brass, forming a recess for holding the selenium, which is spread over the surface. All the evenly matched disks are connected to one end of the circuit, and all the old disks to the other end. The cylindrical form of the cell enables it to be acted upon from all directions, when placed lengthwise in the focus of a parabolic reflector. This is also of great advantage in the Ruhmer type of cell.

Selenium cells possess the remarkable property of recovering the original resistances upon the removal of the source of light.

It is well known that in the case of the radiophone, if a beam of sunlight be thus intercepted by a blackened perforated revolving

disk, a musical note, varying in pitch with the speed of the disk, will be produced in a rubber tube held at the opposite side of the disk. I have here one of the original forms of radiophones.

A piece of apparatus has been devised consisting of a disk with slits near the edge, which is placed near an incandescent lamp, and a selenium cell. If the selenium cell is connected to a telephone and battery, and the disk is rapidly revolved, a musical note will be produced in the telephone, the pitch of which will correspond to the speed of the revolving disk.

Mr. Giltay has recently written me suggesting a very pretty experiment in this line, in which a double vaned Crookes' radiometer is placed between a selenium cell and an arc light shielded by an alum cell. The light from the arc lamp causes the radiometer to revolve intermittently, screening the selenium cell and producing a musical note in the telephone attached thereto, the pitch of which is in accordance with the speed of revolution of the radiometer.

I have here to-night two forms of flame telephone transmitters, one of which was presented to me by Mr. Ruhmer, and the other I have purchased from Mr. Giltay, which I have mounted as you see it here and as illustrated in Fig. 20 (about 24 volts are required, depending upon the selenium cell). In each case you will note that I have an acetylene generator which conveys gas to the interior of an otherwise empty telephone transmitter. The diaphragm of these transmitters is made of pig-skin, or a similar material. A tiny pipe runs from the back of the transmitter, and ends in one case to a single acetylene jet, and in the other case to three acetylene jets. By talking against the pig-skin diaphragm, the gas inside is made to vibrate and produces a manometric flame. This flame throws its light upon a selenium cell, to which is connected a battery and a pair of very sensitive telephones between 100 and 200 ohms for each cell of battery, in which the sounds spoken into the transmitter are most perfectly reproduced. A thin sheet of paper inserted between the flame and the selenium cell serves to cut off all sound. It is self-evident that these telephone receivers might be at any distant point. I have worked them over considerable distances.

In Fig. 21 are shown a number of most interesting applications of the selenium cell in conjunction with a battery and relay, used for starting a motor, ringing a bell, firing a cannon, blowing a horn, and lighting incandescent lamps, all of which experiments

I shall hope to show you in actual operation, as I have had them working most successfully in my laboratory; and you will see that by merely passing my hand before the selenium cell, I can start and stop the motor, turn the light on and off, and ring the bell and blow the horn, or I can fire this cannon, start my phonograph talking, etc. I am indebted to the courtesy of the Marconi Co. for the large relay used in certain of these experiments.

I have here also a 3 h.p. motor, driving a $1\frac{1}{2}$ k.w. generator and

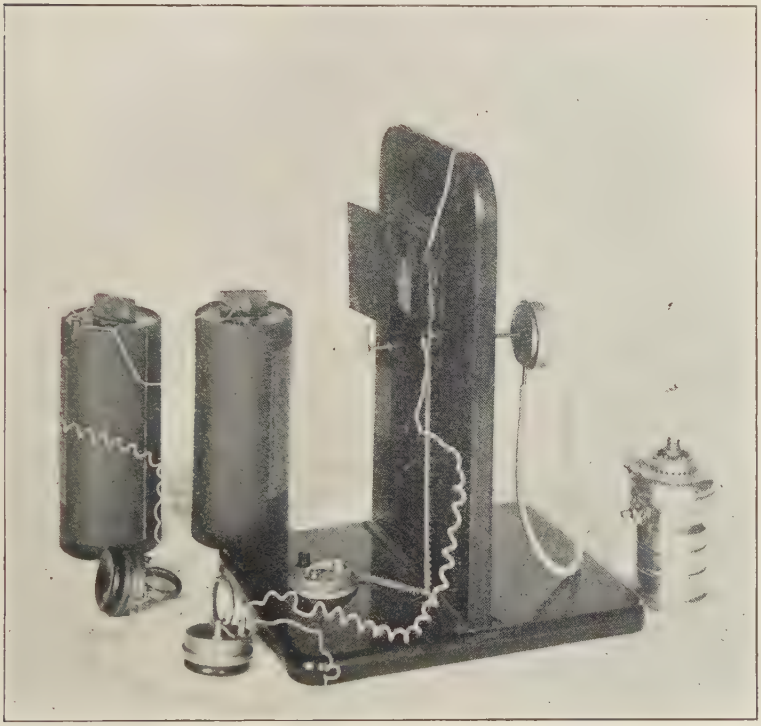


FIG. 20.—Manometric Acetylene Flame Transmitter with Selenium Cell, etc.—(a battery of about 24 volts employed).

supplying these lamps which have been courteously supplied by the General Electric Co.; and by means of this selenium cell, relay, battery and a motor starter, for which I am indebted to the Cutler-Hammer Co., I hope to be enabled to start and stop the motor by merely passing my hand before the selenium cell.

In Fig. 22 is shown a portion of the stage setting at the

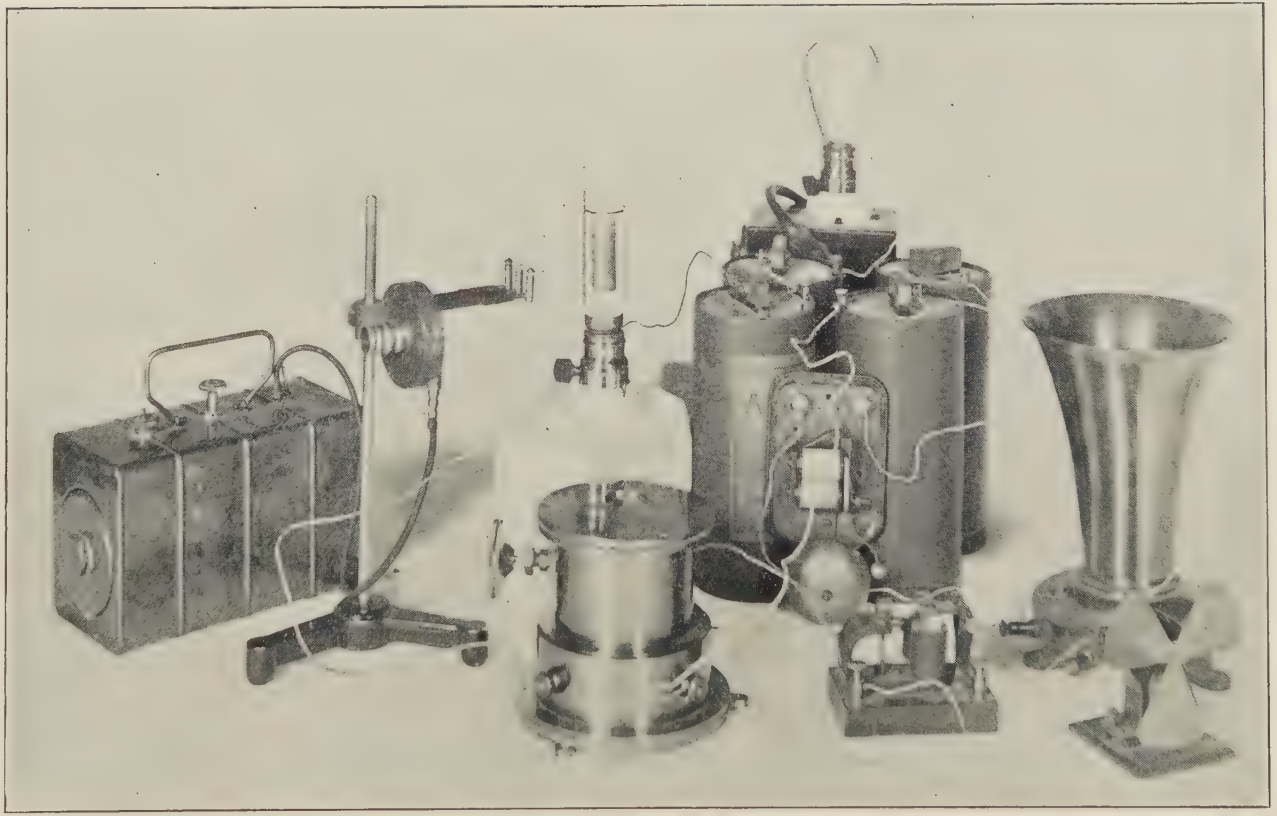


FIG. 21.—Acetylene Flame Apparatus, Ruhmer Selenium Cell, Relays and Battery for Operating. Electric Lamp, Bell, Motor and Horn. (A 3 H.P. Motor and Generator were also similarly operated and a cannon fired.)

lecture, and shows in the foreground the three horse-power motor and generator which supplied a bank of lamps, and which plant was started and stopped many times when the author passed his hand between the acetylene flame and a selenium cell. The frontispiece is a general view of the stage setting in the College of the City of New York, and was taken shortly before Mr. Hammer's lecture.

In 1886 the writer attended a convention of the Edison Association of Illuminating Companies at Rochester, New York, and

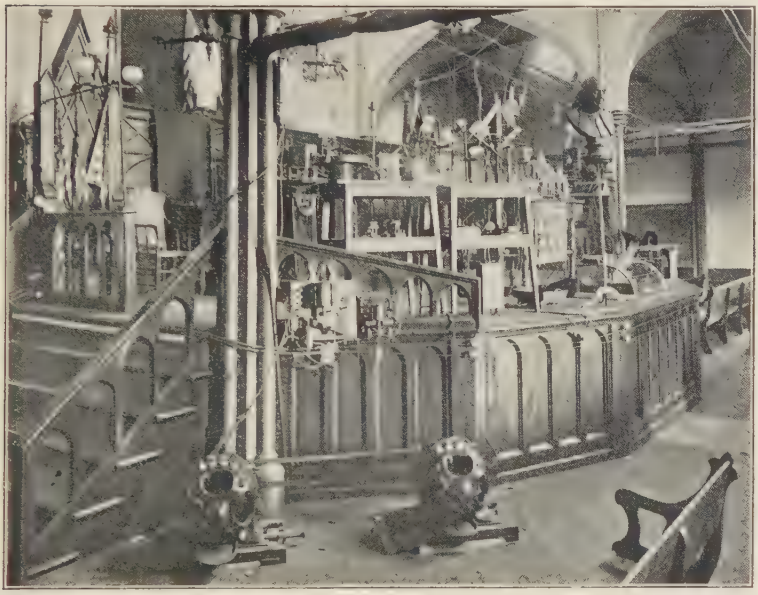


FIG. 22.—Three H.P. Motor and Generator supplying Bank of Lamps and operated by shielding with the hand a Selenium cell from an Acetylene Flame.

during a discussion of contract systems versus meter systems, he gave his experience as chief inspector of central stations of the Edison Company, in dealing with the difficulties met with in supplying light by contract; and he then described a practicable method of utilizing selenium cells to control relays and magnets which would throw off the electric lights on the approach of day and on again at night, thus solving the difficulty of street lighting, and other circuits intended to operate only at night.

On February 12, 1890, in a paper on some experiments with

selenium cells, Mr. Shelford Bidwell showed a relay operated by a selenium cell, which threw on an electric lamp and rang a bell; and he suggested the protection of safes and strong rooms by selenium cells, which would be affected by the light from a burglar's lantern, thus giving an alarm. He also spoke of their being used to give notice of the extinction of railway signal lamps and ship lights, and stated the following: "But I do not at present attach any serious importance to such practical applications of these devices. I regard them simply as offering somewhat attractive illustrations of the effect of light upon the resistance of selenium."

This is an important statement from the greatest authority on the subject of selenium, but to-day it will not hold good.

I hold in my hand a small vial containing some "thermit," which was discovered by Dr. Goldschmidt. It consists of oxide of iron, such as one would get off of a blacksmith's anvil, or from the rolls of a rolling mill, and is mixed with powdered metallic aluminum. A red hot iron or molten cast iron poured into this mixture produces no effect; but if a little barium preparation or magnesium powder be placed on top of this mixture and touched off by a match, an extraordinary reaction takes place, producing a temperature of about 3000° C., and the mechanical equivalent of a kilo (2.2 lbs.) of thermit is about 1,730 horsepower seconds or 1,273 kilowatt seconds.

I have seen some very interesting experiments made in welding girder rails, pipes, etc., by this process, and have here some interesting samples of manganese, chromium, ferro-titanium and other metals prepared in this way.

I have also seen steel safes in which enormous holes had been burned by employing thermit; and it would be possible for a burglar to carry some thermit in his pocket and burn a hole in a safe large enough to insert his arm and extract the valuables.

I also saw in Germany last summer a substance called "anti-thermit," which it is intended to place in the lining of safes to prevent the reaction taking place, thus protecting the safe. But a simple plan would be to place a selenium cell in or near the safe, so that the moment the reaction was started, a signal would be given to the police in a similar manner, as suggested by Mr. Bidwell in the case of the burglar's bull's-eye lantern.

An important commercial application of the selenium cell has recently been made by Mr. Ernest Ruhmer in connection with his electrically controlled buoy illustrated in Fig. 23.

Pintsch has constructed a large number of buoys containing compressed gas, which would last from one month to upwards of a year; but it was heretofore necessary to burn these lights day and night, it being often impracticable by reason of distance at which they were placed, and frequency of storms, etc., to switch off the gas so that it would not burn during the daytime.

Mr. Ruhmer has placed one of his selenium cells in the top of such a buoy connected with a switching device which, as soon as the sun rises in the morning, causes the selenium cell to reduce its resistance, this causing the switching device to turn off the gas, which is again turned on upon the

FIG. 23.—Pintsch Gas Buoy Controlled by a Ruhmer Selenium Cell, Battery and Switch Mechanism.

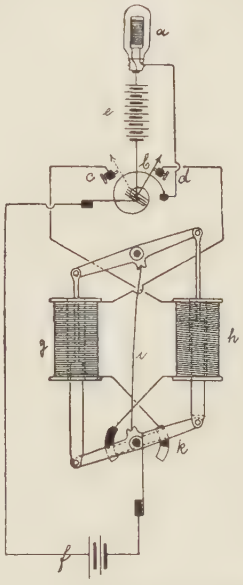


FIG. 24.—Diagram of Circuits of "Selenium" Buoy.

increase of resistance of the selenium cell by the approach of nightfall, or if desired in the case of a storm coming up. A buoy containing sufficient gas for one month could thus be made to answer without recharge for from three to five months.

The arrangement of the circuits as originally devised by Mr. Ruhmer is shown in Fig. 24. The voltmeter needle has been replaced by a relay, and the apparatus simplified. A single dry cell is interpolated in the selenium cell circuit, as usually employed on the buoy; and this cell will last a year or more, and with the relay, it is placed in the bottom of the buoy and arranged to be absolutely waterproof.

When I was in Berlin last August, one of these buoys had been in operation since the previous October, turning the light on and off every night and morning; and Mr. Ruhmer has recently written me that it is still operating successfully, as are others which he has placed near Hamburg and in the Baltic Sea.

Mr. Ruhmer has also constructed an apparatus employing the selenium cell to which he has given the name "photographophone," which is one of the most remarkable pieces of scientific apparatus that it has ever been my pleasure to see. Figs. 25, 26

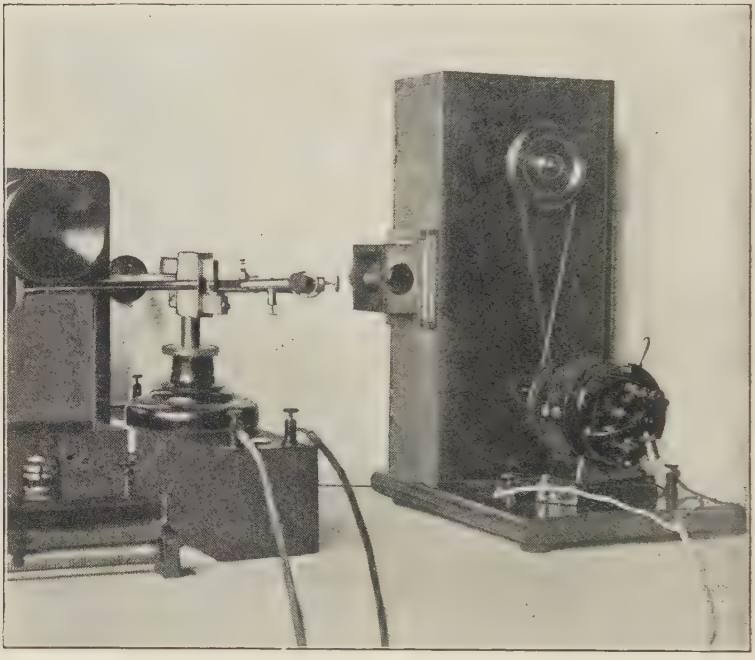


FIG. 25.—Ernest Ruhmer's Photographophone, Showing Exterior View, together with Telephone Transmitter and Arc Lamp.

and 27 illustrate the general construction of the apparatus, which I shall further illustrate by accompanying lantern slides. In Fig. 28 the apparatus is shown diagrammatically and in Fig. 27 the inventor is shown listening to the photographophone reproducing speech and music. It consists of a box containing a gelatine or celluloid film, such as employed in moving picture machines, which is driven at high speed by means of an electric motor. In the front face of the box is set a cylindrical lens about the size of one's little finger. A short

distance away from the box is placed an arc lamp and a telephone. Words spoken or sung into the telephone superimpose the waves in the telephone circuit upon the current flowing in the arc light circuit, and cause a corresponding variation in the light of the arc. The rays from the arc lamp pass through the cylindrical lens already referred to, and are caused to fall in sharp white lines on the moving sensitive film. This film, upon being taken out of the box and developed, shows a series of perpendicular striations parallel to one another, which are really a photographic record of the sound waves originally entering the telephone transmitter. Where the striations are fine and close together the pitch is high, but where they are broader and farther apart the pitch is low. Strips of the films or photograms are shown in Fig. 29. The developed film is next placed back into the box and the motor again started. The arc lamp remains in its original position, but

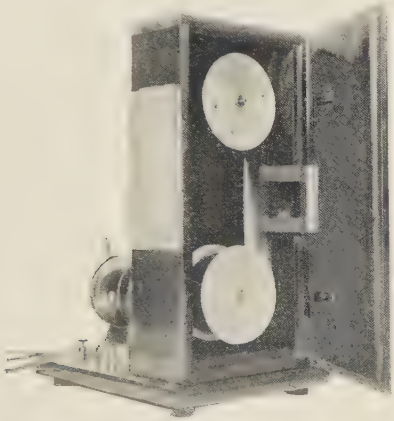


FIG. 28.—Showing Interior of Ruhmer's Photographophone.

burns steadily as the telephone is not operated. The rays from the arc lamp passing through the lens are therefore quite uniform, and the moving gelatine strip acts as a screen to cut off these rays, allowing the light intermittently to fall upon the selenium cell at the back of the box, producing a variation in its resistance and a corresponding effect in the telephone receivers connected thereto. A battery is also interpolated in the circuit with the selenium cells and the telephones. By holding these telephones to the ear, the reproduction of the sound is perfect, as I can vouch for from personal experience with the apparatus.

Mr. Ruhmer contemplates utilizing this photographophone as a receiving instrument with its wireless telephone system, in which he employs a beam of light, as already described.

Mr. Shelford Bidwell has also made a device for producing pictures or writing at a distance by combining the properties of selenium with the chemical telegraph.

Various inventors have endeavored to solve the problem of seeing what goes on at a distance by employing selenium. Among these are Perosino, Senlecq, de Paiva, Cary, Sawyer, Larroque, Nipkow, Gemmill, Liesegang, Heinzerling, Edison, Stern, Jan Szczepanik, Dussaud, Otto von Bronk, von St. Schneider, Ayrton and Perry, Korn, and others, who have proposed various methods employing images thrown on ground glass or through a photograph negative, or upon mirrors swinging synchronously, or by

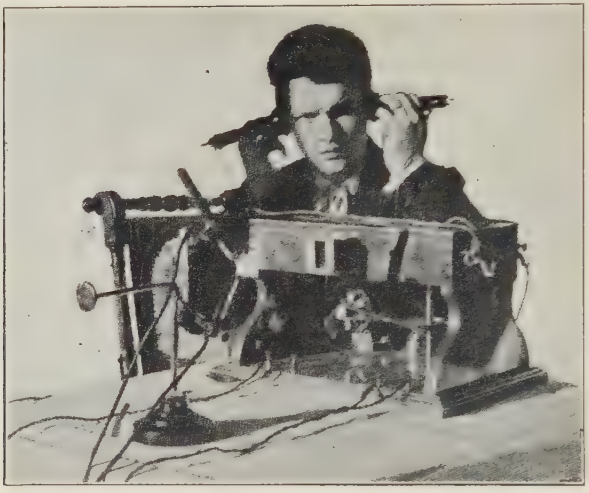


FIG. 27.—Mr. Ernest Ruhmer Listening to his Photographophone.

using revolving perforated screens, for cutting off the beams of light, multiple selenium cells which would be affected by high lights and low lights of the original picture, etc., these devices effecting some method of illumination at the receiving end or producing an electrochemical action such as is produced by the usual chemical telegraph systems, or controlling an electropantograph system such as Gray's telautograph. These various inventions have been termed the telescope, telephote, telectroscope and the telephotograph. But these devices have thus far reached little further than descriptive matter, drawings and crude experiments.

Various people have suggested the use of selenium cells for photometric purposes; and it is interesting to note that Mr.

Latimer Clark suggested this application the evening in which Mr. Willoughby-Smith first brought to public notice the phenomena of variation in resistance of selenium when exposed to light, to which I have already referred.

Mr. Fritts has suggested making a form of photometer which would be sensitive to lights of different color, as well as of varying candle power, by employing as a film on the surface of his cell a gold foil which transmits green rays, a silver foil the blue rays, and so on; and suggests that a solid transparent conducting film which would transmit all of the rays would be far better and thus remove the color stumbling block in photometric work.

Sir William Crookes has constructed an exceedingly interesting type of radiometer, in which he has coated the revolving vanes on one side with selenium, and on the other with chromic acid. He

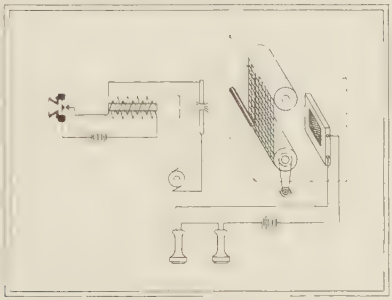


FIG. 28.—Showing General Arrangement of Circuits of Ruhmer's Photographophone.

found that the white light from a sperm candle repelled the selenium, while the yellower light of the wax candle repelled the chrome, thus indicating the relative absorptive powers of the different substances for rays of different refrangibility, resulting in mechanical motion; just as the same selective capacity operates in photography as chemical action.

In 1891 Prof. Barnard of Lick Observatory employed a selenium cell as a device for automatically detecting comets, and Minchin has employed the selenium cell quite extensively in his astronomical investigations.

In Fig. 30 is shown a curve which Mr. Ruhmer recently sent me which shows some observations made by means of his selenium cell during an eclipse, these being the only observations which anyone was enabled to make at that time, on account of stormy weather. Mr. Ruhmer has prepared an interesting paper bearing on this and other applications of the selenium cell to meteorology. He made his observations on October 31, 1902.

Selenium is found in Vesuvian lava, and in natural sulphur as a sulphur selenide in the Lispari Islands. It is also found in Norway and other iron pyrites. It occurs in meteoric iron and in such rare metals as eucarite as a selenide of silver and copper in Sweden and Chili; crooksite, a selenide of copper and thallium with a little silver, from Norway; as clausthalite, a selenide of lead in the Hartz Mountains, from Zinken and Clausthal, in Inverg, Rheinberg, Saxony, Rio Tinto, Spain, Mendoza, South America; as riolite at Culebras, Mexico; as Lehrbachite, a

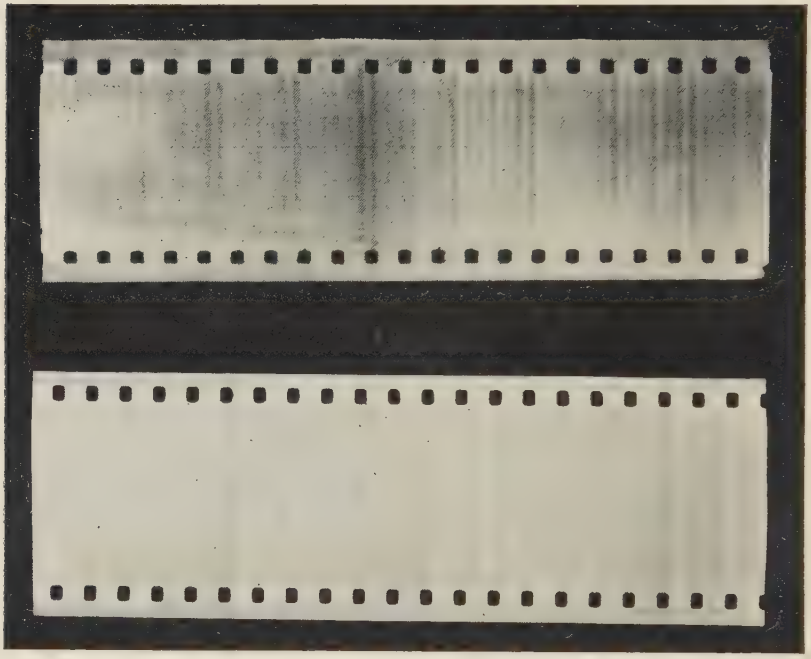


Fig. 29.—Photogram as used in Ruhmer's Photographophone (High Pitch Tones above, Low Pitch below).

selenide of mercury and lead from the Hartz Mountains; as zorgite, a selenide of copper and lead from Glasbach in the Hartz Mountains. Selenium, although widely distributed over the globe, occurs only in small quantities and in some instances is found in native state.

Selenium is placed among the rare metals. Chemically pure crystalline selenium costs about $1.00 per gramme; and the ordinary commercial article about 10 cents per gramme.

The Bibliography of selenium is quite extensive. Those interested in the subject will find an excellent paper by Mr. A. P.

Saunders in the *Jour. of Chem.* for June, 1900. The paper contains many references, and is entitled "Allotropic Forms of Selenium."

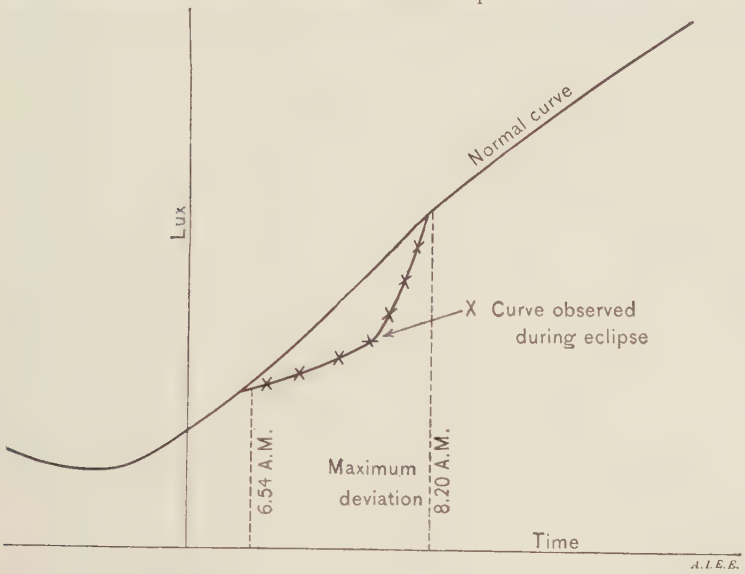


FIG. 30.—Curve Taken with Ruhmer Cell During Eclipse, Oct. 31, 1902.

THE TREATMENT OF DISEASE BY ULTRA-VIOLET RAYS.

PROF. NIELS R. FINSEN.

Some professional matters detained the writer in Copenhagen last summer for several weeks, and during his stay in that city he had the privilege of visiting the Finsen Light Institute at Rosenvaengat, a suburb of Copenhagen, and was enabled to investigate the system for the treatment of disease by light, inaugurated by Dr. Niels R. Finsen. In Figs. 31 and 32 are shown views of the operating room at the Finsen Institute, where a large number of patients from various parts of Europe were undergoing treatment at the time of my visit.

Dr. Finsen has conducted very extensive and most painstaking

researches into the bactericidal effects of light, and he has found the violet end of the spectrum to possess remarkable curative powers, and he has also found that by utilizing the blue, violet and ultra-violet rays of the spectrum, those loathsome diseases of tuberculosis of the skin and lupus, diseases which have baffled surgical skill heretofore, have been successfully combated.

It has recently been stated that in New York City alone there are annually 20,000 cases of tuberculosis, with 8,000 deaths; and there is probably no disease with which mankind is afflicted which compares in deadly character to tuberculosis.

In affecting certain of the internal organs, it is known as consumption, and appearing externally, attacking the skin and underlying tissues, it is known as lupus vulgaris. As a rule, it appears in single patches, most frequently attacking the face, especially the nose, cheek and mouth. It may, however, attack the extremities, or, in fact, any portion of the body and even mucous membranes. Fortunately, lupus is rather rare in this country, although very common in Europe.

Koch and others have fully demonstrated that tuberculosis is due to the presence of specific organisms named "tubercle bacilli," which have been found to be present in both the internal and cutaneous forms of the disease.

Doubtless many present remember the "blue glass craze" which swept over the country in 1876, or thereabouts.

I have with me here a copy of General A. J. Pleasonton's book entitled "Blue and Sunlights, Their Influence upon Life and Disease," which I picked up in a second-hand book store some years ago; and I would commend the examination of this book to all who are interested in the subject. General Pleasonton and his system were condemned to both abuse and ridicule. Dr. Finsen, however, says, "The General was absolutely on the right track."

For a considerable time Finsen's work received little credence and no encouragement; but he persisted in his investigations, and the results secured by him finally bore fruit, and to-day the world rings with his praises. In all parts of the civilized world his work is being taken up, and institutes are being founded for the treatment of disease by light rays—particularly the ultra-violet light. In England the initiative was taken by Queen Alexandra, and in Russia by her sister, the Czarina, they both investigating the system while visiting their father, the King of

FIG. 31.—Showing Main Operating Room, Finsen Institute, Copenhagen.

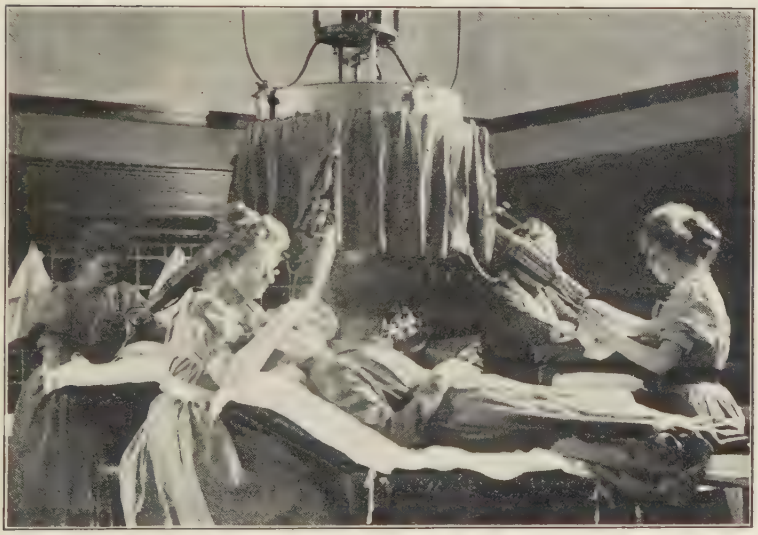


FIG. 32.—Showing Arc Lamp and Four Finsen Tubes in Use at One Time.

Denmark. Much has also already been done in the United States.

It will be remembered that during Queen Elizabeth's reign a certain court physician recommended strongly that patients suffering from smallpox should be kept in a room, the decorations of which, including the hangings, bed draperies, etc., should be red in color, claiming that the red light had a soothing effect upon the irritated portions of the skin, lessening the severity of the disease. Little importance was attached to this method, and the originator of it was branded as a Charlatan.

Prof. Finsen has, however, found that this method of treatment of smallpox is of paramount importance. He has placed patients in a room into which the sun's rays could only penetrate through sheets of red glass, just as they would penetrate a photographic dark room; and he has found that patients placed in such a room prior to the most painful and most dangerous suppuration stage setting in, that suppuration has been entirely prevented and that the scarring has been in nearly all cases absolutely prevented, and in the few cases where there was any scarring, it was hardly perceptible. The disease has been in a much milder form, the fever usually accompanying the eruption disappearing, and the temperature remaining normal.*

He has found that the use of ultra-violet light on these patients very much aggravated the disease, and even in cases where patients were almost cured and they have been allowed to go out into the sunlight, the disease has at once been aggravated.

In connection with his investigations into the effects of light Finsen made some interesting and ingenious experiments upon earth-worms placed in a box, one-half of which was covered with red glass and the other half blue glass; and he found the blue light irritated the worms so they invariably crawled under the red glass, and a chameleon, placed with its body midway between the glasses, turned almost jet black under the influence of the blue rays, while that portion under the red glass remained nearly white, which Prof. Finsen says showed that the chameleon was altering its pigment cells to lessen the irritating effects of the blue light.

The ultra-violet end of the spectrum contains the most refrangible rays, and it is these rays which are so harmful in cases of smallpox; and t is also these actinic rays which produce sun-

* Prof. Finsen has recently written the author that placing the patients in a dark room is fully as efficacious as placing them in a room lighted with red rays only, the important thing being to keep the patient from exposure to the actinic rays.

burning, which one often experiences in the Alps, or any high altitude where the temperature may be considerably below zero; and there are doubtless many present who have experienced considerable effect similar to sunburning by working in close proximity to arc lamps.

While these ultra-violet rays are so harmful in the case of smallpox, they are of the precise nature which is most desirable in the treatment of such diseases as tuberculosis of the skin or lupus vulgaris. These rays not only destroy the bacilli, but they excite and stimulate nutrition and excite activity in granulation, thus assisting very greatly in the rapid recovery from the disease.

Doubtless the rays emanating from the sun are very rich in blue, violet and ultra-violet light; but the atmosphere readily absorbs these rays, and while Prof. Finsen for a time used the sun's rays in the treatment of tuberculosis of the skin and lupus he found that by employing the arc light the same effect could be produced in a very much shorter space of time; and that he was in this way, also, independent of weather conditions.

The arc light is much richer in ultra-violet rays than the sunlight; and Broca and Chatin of Paris have found that by placing an iron core inside of the positive carbon electrode, this arc was still richer in ultra-violet light, and Görl of Erlangen has constructed a form of aluminum arc, in which four arcs were formed between five aluminum electrodes. I have here a modification of Görl's lamps constructed by Messrs. Waite & Bartlett of this city, in which there are four iron electrodes forming three iron arcs in series, which produce an intense source of ultra-violet light, which I shall presently show in operation.

Bang and others have also made arc lamps employing terminals of iron.

It is claimed that by employing the iron arc the same results which take an hour and ten minutes by means of the carbon arc can be accomplished in twenty minutes to half an hour; and also that so intense are these ultra-violet rays it is not necessary to use pressure to drive the blood away from the diseased part, and it is also unnecessary to use water to cool the rays.*

Drs. Piffard and Jamieson have suggested the use of suprarenal extract in the form of adrenalin chloride, which the former prefers to introduce into the skin around the diseased spot

* Prof. Finsen has recently written the author emphatically asserting that iron electrodes are not as efficacious as carbon electrodes as the rays from the iron arc, he claims, do not penetrate as deeply as the rays from the carbon arc.

by cataphorisis, thus producing a whitened area from which the blood has been withdrawn, which enables the treatment of this portion by the ultra-violet light, without pressure being applied, and the blood does not return for half an hour or more. The cataphoric electrode is covered with a thickness of lentine saturated with adrenalin connected with a positive pole of the battery, using a current of from three to four milli-amperes, the bleaching taking from four to five minutes' time.

The Roentgen rays have been found very effective in the treatment of certain diseases, especially where hard tubes are employed, and as we are considering particularly the treatment of lupus vulgaris, I would call attention to Fig. 33, which repre-

FIG. 33.—Lupus Vulgaris Cured by X-rays.

sents a patient treated by my friend Dr. William H. King of this city, in which the X-rays successfully cured a case of lupus vulgaris brought on by the patient's pricking a tiny boil on the side of his nose with a pin taken from the lapel of the coat of a friend who was suffering from tuberculosis (consumption). The rapid progress of the disease is shown in the illustration and was taken three weeks after using the pin, and was largely augmented by the man's age (45), and his being in poor health (a chronic rheumatic). Two bacteriological examinations showed conclusive evidence of the presence of tubercle bacilli.

In Fig. 34 is shown the original blue lens used by Finsen when employing sunlight. It consists of a flask full of light blue ammoniacal sulphate of copper. The bottle with its contents

makes a plano-convex lens. The sunlight passing through this is found to work very well; but it was too slow, and the sun was frequently obscured. Finsen later used plain water, finding that the blue water cut off most of the ultra-violet rays and he found the clear water very largely absorbed the ultra-red rays which caused the heat.

In Fig. 35 is shown a form of telescope which is now adapted in standard practice at the Finsen Institute. It contains four rock crystal lenses, which act to cut off considerable of the heat rays; but allow the ultra-violet light to pass through it.

FIG. 34.—Finsen's Original Blue Lens for Use with Sunlight.

It will be remembered that ordinary glass cuts off almost all of the ultra-violet rays, whereas a block of rock crystal 4.4 mm. thick will allow 60 per cent. of the ultra-violet to pass through it.

A part of the heat is also absorbed by the distilled water which is contained inside of the telescope. In order to keep this water cool, there is an outside jacket on the telescope, through which circulating water may be passed for this purpose. In Fig. 36 is shown the method of arrangement of the telescope and the arc lamp; and in Fig. 32 is shown a set of four of these telescopes arranged around the arc lamp and in actual operation. The arc lamp uses from 40 to 80 amperes and operates at 45 to 50 volts.

Blood is opaque to ultra-violet light, and it is therefore necessary to drive the blood away from the diseased portion which is to be treated. This is accomplished by what is known as a pressure glass shown in Fig. 37. It consists of a plano-convex lens of rock crystal kept cool by circulating water—the glass acting to focus the light on the diseased portion, and also to exert considerable pressure there.

The patient does not suffer from exposure to the rays; but after the treatment, which is usually an hour and ten minutes per day, he appears to be considerably sunburned. He is then allowed to recuperate until the next day, and the treatment is then repeated. After a series of these treatments, the patient is sent away apparently cured. Sometimes he does not return; but more often he must come back for a second or third, and even more series of treatments, due to the fact that certain of the

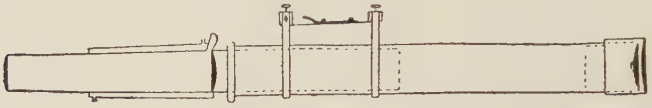


FIG. 35.—Finsen Telescope Tube, for Use with Carbon Arc Light.

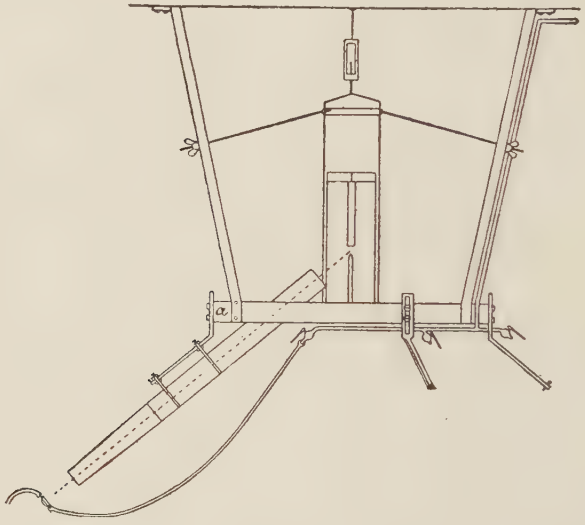


FIG. 36.—Showing Arrangement of Arc Lamp and Finsen Tubes.

microbes which have been deep-seated have worked their way to the surface, the disease having started anew.

It is said that out of over 600 cases treated at Copenhagen, there have been only 1 to 2% of failures due to fault in the treatment; but there have been cases where the disease has been in such an advanced stage and for such a very long period that it has not yielded successfully. But I was informed that in the majority of cases after very few treatments, the patients are dismissed absolutely cured. In order that you may properly

FIG. 38.—Showing Lupus Vulgaris Patients Before and After Treatment with Ultra-Violet Light at the Finsen Institute, Copenhagen.

appreciate the remarkable results which have been secured by Prof. Finsen; and the stupendous importance which his successful combating of these loathsome forms of disease represents to many of the most sorely afflicted people of this world, I have inserted in my paper several photographs, see Fig. 38, which I secured at the Finsen Institute, of patients afflicted with lupus vulgaris—these pictures showing them before and after the treatment with the ultra-violet rays produced by the arc light. I feel that their presentation in this paper requires no apology; on the contrary, electrical engineers should feel a sense of pride that in the use of the arc light in this remarkable advance in medicine and surgery, their profession has contributed in no small degree.

Those caring to look up these and similar cases, will find full descriptions in English in "Phototherapy after Finsen's Methods," by Valdemar Bie, M.D., Prof. Finsen's Assistant (published

Fig. 37.—Pressure Lens.

by Lippincott), or Die Bekämpfung des Lupus Vulgaris von Niels R. Finsen (Gustav Fischer, Jena), and Die Finsen Therapie und ihr gegenwärtigen Stand in der Dermatologie, von Dr. Forchhammer (J. Cohen's Buchdruckereien, Kopenhagen).

The little cut of Prof. Finsen which heads this article is from an autograph portrait which Prof. Finsen presented to the writer, and it is sad to contemplate that this man who has conferred such a priceless boon upon humanity is himself an invalid, suffering from an incurable disease, and one which has made it at times well nigh impossible for him to prosecute his work.

The Finsen Institute was established in 1896, through the munificence of Copenhagen's public-spirited citizens, and through a gift by the city of the property on which it was erected.

The lecturer desires to express his appreciation of the services rendered by his assistants, Messrs. Varley, Lawton, Brown, Webb, Scheerer and Dow, and also to acknowledge the courtesies extended by the New York Edison Co.

LIST OF WORKS

ON

ELECTRICAL SCIENCE

PUBLISHED AND FOR SALE BY

D. VAN NOSTRAND COMPANY,

23 Murray and 27 Warren Streets, New York.

ABBOTT, A. V. The Electrical Transmission of Energy. A Manual for the Design of Electrical Circuits. New Edition, revised and rewritten. With many Diagrams and Engravings and Folding Plates. 8vo, cloth. In press.

ANDERSON, GEO. L., A.M. (Capt. U.S.A.). Handbook for the Use of Electricians in the operation and care of Electrical Machinery and Apparatus of the United States Seacoast Defenses. Prepared under the direction of Lieut.-General Commanding the Army. Illustrated. 8vo, cloth. $3.00.

ARNOLD, E. Armature Windings of Direct-Current Dynamos. Extension and Application of a general Winding Rule. Translated from the original German by Francis B. DeGress, M.E. Illustrated. 8vo, cloth. $2.00.

ATKINSON, A. A., Prof. (Ohio Univ.). Electrical and Magnetic Calculations. For the use of Electrical Engineers and others interested in the Theory and Application of Electricity and Magnetism. Second Edition, revised. Illustrated. 8vo, cloth. Net, $1.50.

ATKINSON, PHILIP. The Elements of Dynamic Electricity and Magnetism. Fourth Edition. Illustrated. 8vo, cloth. $2.00.

Elements of Electric Lighting, including Electric Generation, Measurement, Storage, and Distribution. Tenth Edition, fully revised and new matter added. Illustrated. 8vo, cloth. $1.50.

Power Transmitted by Electricity and Applied by the Electric Motor, including Electric Railway Construction. Illustrated. Fourth Edition, fully revised and new matter added. 8vo, cloth. $2.00.

BADT, F. B. New Dynamo Tender's Handbook. 70 Illustrations. 16mo, cloth. $1.00.

Electric Transmission Handbook. Illustrations and Tables. 16mo, cloth. $1.00.

Incandescent Wiring Handbook. Fourth Edition. Illustrations and Tables. 12mo, cloth. $1.00.

Bell-Hanger's Handbook. Third Edition. Illustrated. 12mo, cloth. $1.00.

BIGGS, C. H. W. First Principles of Electricity and Magnetism. Illustrated 12mo, cloth. $2.00.

BLAKESLEY, T. H. Papers on Alternating Currents of Electricity. For the use of Students and Engineers. Third Edition, enlarged. 12mo, cloth. $1.50.

BOTTONE, S. R. Electrical Instrument-Making for Amateurs. A Practical Handbook. Enlarged by a chapter on "The Telephone." Sixth Edition. With 48 Illustrations. 12mo, cloth. 50 cents.

BOWKER, WM. R. Dynamo, Motor, and Switchboard Circuits for Electrical Engineers: a practical book dealing with the subject of Direct, Alternating, and Polyphase Currents. With over 100 Diagrams and Engravings. 8vo, cloth. Illustrated. Net, $2.25.

CLARK, D. K. Tramways: Their Construction and Working. Embracing a Comprehensive History of the System, with Accounts of the Various Modes of Traction, a Description of the Varieties of Rolling Stock, and Ample Details of Cost and Working Expenses; with Special Reference to the Tramways of the United Kingdom. Second Edition, revised and rewritten. With over 400 Illustrations. Contains a section on Electric Traction. 8vo, cloth. $9.00.

CROCKER, F. B., and WHEELER, S. S. The Practical Management of Dynamos and Motors. Revised and enlarged. Illustrated. Sixteenth Thousand. 12mo, cloth. $1.00.

CROCKER, F. B. Electric Lighting. A Practical Exposition of the Art for the use of Electricians, Students, and others interested in the Installation or Operation of Electric-Lighting Plants. Volume I.: The Generating Plant. New Edition, revised and rewritten. In press. Volume II.: Distributing System and Lamps. Fourth Edition. 8vo, cloth. Each, $3.00.

DESMOND, CHAS. Electricity for Engineers. Part I.: Constant Current. Part II.: Alternate Current. Revised Edition. Illustrated. 12mo, cloth. $2.50.

DYNAMIC ELECTRICITY; Its Modern Use and Measurement, chiefly in its application to Electric Lighting and Telegraphy, including: 1. Some Points in Electric Lighting, by Dr. John Hopkinson. 2. On the Treatment of Electricity for Commercial Purposes, by J. N. Shoolbred. 3. Electric-Light Arithmetic, by R. E. Day, M.E. 18mo, boards. (No. 71 Van Nostrand's Science Series.) 50 cents.

EMMETT, WM. L. Alternating-Current Wiring and Distribution. 16mo, cloth. Illustrated. $1.00.

EWING, J. A. Magnetic Induction in Iron and other Metals. Third Edition, revised. Illustrated. 8vo, cloth. $4.00.

FISKE, BRADLEY A., Lieut., U.S.N. Electricity in Theory and Practice; or, The Elements of Electrical Engineering. Tenth Edition. 8vo, cloth. $2.50.

FLEMING, J. A., Prof. The Alternate-Current Transformer in Theory and Practice. Vol. I.: The Induction of Electric Currents. 500 pp. Fifth Issue. Illustrated. 8vo, cloth. $5.00. Vol. II.: The Utilization of Induced Currents. Third Issue. 594 pp. Illustrated. 8vo, cloth. $5.00.

Electric Lamps and Electric Lighting. 8vo, cloth. $2.50.

FOSTER, H. A. Electrical Engineers' Pocket Book. With the Collaboration of Eminent Specialists. A handbook of useful data for Electricians and Electrical Engineers. With innumerable Tables, Diagrams, and Figures. The most complete book of its kind ever published, treating of the latest and best Practice in Electrical Engineering. Third Edition, revised. Pocket size, full leather, 1000 pp. $5.00.

GORDON, J. E. H. School Electricity. 12mo, cloth. $2.00.

GORE, GEORGE, Dr. The Art of Electrolytic Separation of Metals (Theoretical and Practical). Illustrated. 8vo, cloth. $3.50.

GRAY, J. Electrical Influence Machines: Their Historical Development and Modern Forms. With Instructions for making them. Second Edition, revised and enlarged. With 105 Figures and Diagrams. 12mo, cloth. Illustrated. $2.00.

GUILLEMIN, AMEDÉE. Electricity and Magnetism. Translated, revised, and edited by Prof. Silvanus P. Thompson. 600 Illustrations and several Plates. Large 8vo, cloth. $8.00.

GUY, ARTHUR F. Electric Light and Power: Giving the result of practical experience in Central-Station Work. 8vo, cloth. Illustrated. $2.50.

HAMMER, W. J. Radium, and Other Radio-active Substances; Polonium, Actinium, and Thorium. With a consideration of Phosphorescent and Fluorescent Substances, the properties and applications of Selenium, and the treatment of disease by the Ultra-Violet Light. With Engravings and Plates. 8vo, cloth. Illustrated. $1.00.

HASKINS, C. H. The Galvanometer and its Uses. A Manual for Electricians and Students. Fourth Edition, revised. 12mo, morocco. $1.50.

Transformers: Their Theory, Construction, and Application Simplified. Illustrated. 12mo, cloth. $1.25.

HAWKINS, C. C., and WALLIS, F. The Dynamo: Its Theory, Design, and Manufacture. 190 Illustrations. 8vo, cloth. $3.00.

HOBBS, W. R. P. The Arithmetic of Electrical Measurements. With numerous examples, fully worked. Ninth Edition. 12mo, cloth. 50 cents.

HOUSTON, E. J., Prof. A Dictionary of Electrical Words, Terms, and Phrases. Fourth Edition, rewritten and greatly enlarged. 570 Illustrations. Large 8vo, cloth. $7.00.

INCANDESCENT ELECTRIC LIGHTING. A Practical Description of the Edison System, by H. Latimer. To which is added: The Design and Operation of Incandescent Stations, by C. J. Field; A Description of the Edison Electrolyte Meter, by A. E. Kennelly; and a Paper on the Maximum Efficiency of Incandescent Lamps, by T. W. Howell. Illustrated. 16mo, cloth. (No. 57 Van Nostrand's Science Series.) 50 cents.

INDUCTION COILS: How Made and How Used. Third Edition. 16mo, cloth. (No. 53 Van Nostrand's Science Series.) 50 cents.

JEHL, FRANCIS, Member A.I.E.E. The Manufacture of Carbons for Electric Lighting and other purposes. Illustrated with numerous Diagrams, Tables, and Folding Plates. Illustrated. 8vo, cloth. $4.00.

KAPP, GISBERT, C.E. Electric Transmission of Energy and its Transformation, Subdivision, and Distribution. A Practical Handbook. Fourth Edition, thoroughly revised. 12mo, cloth. $3.50.

Alternate-Current Machinery. 190 pp. Illustrated. (No. 96 Van Nostrand's Science Series.) 50 cents.

Dynamos, Alternators, and Transformers. Illustrated. 8vo, cloth. $4.00.

KELSEY, W. R. Continuous-Current Dynamos and Motors, and their Control; being a series of articles reprinted from the "Practical Engineer," and completed by W. R. Kelsey, B.Sc. With Tables, Figures, and Diagrams. 8vo, cloth. Illustrated. $2.50.

KEMPE, H. R. The Electrical Engineer's Pocket-Book: Modern Rules, Formulæ, Tables, and Data. Second Edition, with additions. 32mo, leather. $1.75.

A Handbook of Electrical Testing. Fifth Edition. 200 Illustrations. 8vo, cloth. $6.00.

KENNELLY, A. E. Theoretical Elements of Electro-Dynamic Machinery. Vol. I. Illustrated. 8vo, cloth. $1.50.

KILGOUR, M. H., SWAN, H., and **BIGGS, C. H. W.** Electrical Distribution: Its Theory and Practice. Illustrated. 8vo, cloth. $4.00.

LIVERMORE, V. P., and **WILLIAMS, J.** How to Become a Competent Motorman: being a practical treatise on the proper method of operating a street-railway motor-car; also giving details how to overcome certain defects. 16mo, cloth. Illustrated. $1.00.

LOCKWOOD, T. D. Electricity, Magnetism, and Electro-Telegraphy. A Practical Guide and Handbook of General Information for Electrical Students, Operators, and Inspectors. Fourth Edition. Illustrated. 8vo, cloth. $2.50.

LORING, A. E. A Handbook of the Electro-Magnetic Telegraph. Fourth Edition, revised. 16mo, cloth. (No. 39 Van Nostrand's Science Series.) 50 cents.

MANSFIELD, A. N. Electromagnets: Their Design and Construction. (Van Nostrand's Science Series, No. 64.) 50 cents.

MARTIN, T. C., and **WETZLER, J.** The Electro-Motor and its Applications. Fourth Edition, with an Appendix on the Development of the Electric Motor since 1888, by Dr. L. Bell. 300 Illustrations. 4to, cloth. $3.00.

MAVER, WM., Jr. American Telegraphy and Encyclopedia of the Telegraph Systems, Apparatus, Operations. 430 Illustrations. Fifth Edition, revised. 8vo, cloth. $3.50

NIPHER, FRANCIS E., A.M. Theory of Magnetic Measurements. With an Appendix on the Method of Least Squares. 12mo, cloth. $1.00.

NOLL, AUGUSTUS. How to Wire Buildings. A Manual of the Art of Interior Wiring. Fourth Edition. 8vo, cloth. Illustrated. $1.50.

OHM, G. S., Dr. The Galvanic Circuit Investigated Mathematically. Berlin, 1827. Translated by William Francis. With Preface and Notes by the Editor, Thos. D. Lockwood. 12mo, cloth. (No. 102 Van Nostrand's Science Series.) 50 cents.

OUDIN, MAURICE A. M. S. Standard Polyphase Apparatus and Systems. Illustrated with many Photo-Reproductions, Diagrams, and Tables. Third Edition, revised. 8vo, cloth. $3.00.

PALAZ, A. Treatise on Industrial Photometry. Specially applied to Electric Lighting. Translated from the French by G. W. Patterson, Jr., Assistant Professor of Physics in the University of Michigan, and M. R. Patterson, B.A. Second Edition. Fully Illustrated. 8vo, cloth. $4.00.

PARR, G. D. A. Electrical Engineering Measuring Instruments, for Commercial and Laboratory Purposes. With 370 Diagrams and Engravings. 8vo, cloth. Illustrated. Net, $3.50.

PARSHALL, H. F., and **HOBART, H. M.** Armature Windings of Electric Machines. With 140 full-page Plates, 65 Tables, and descriptive letter-press. 4to, cloth. $7.50.

PERRINE, F. A. C., A.M., D.Sc. Conductors for Electrical Distribution: Their Manufacture and Materials, the Calculation of Circuits, Pole-Line Construction, Underground Working, and other Uses. 8vo, cloth. Illustrated. $3.50.

PERRY, NELSON W. Electric Railway Motors: Their Construction, Operation, and Maintenance. An Elementary Practical Handbook for those engaged in the management and operation of Electric Railway Apparatus, with Rules and Instructions for Motormen. 12mo, cloth. $1.00.

PLANTÉ, GASTON. The Storage of Electrical Energy, and Researches in the Effects created by Currents combining Quantity with High Tension. Translated from the French by Paul B. Elwell. 89 Illustrations. 8vo. $4.00.

POPE, F. L. Modern Practice of the Electric Telegraph. A Handbook for Electricians and Operators. An entirely new work, revised and enlarged, and brought up to date throughout. Illustrations. 8vo, cloth. $1.50.

RAYMOND, E. B. Alternating-Current Engineering, Practically Treated. With many Figures and Diagrams. In press.

SALOMONS, Sir DAVID, M.A. Electric-Light Installations. A Practical Handbook. Seventh Edition, revised and enlarged. Vol. I.: Management of Accumulators. Illustrated. 12mo, cloth. $1.50. Vol. II.: Apparatus. Illustrated 12mo, cloth. $2.25. Vol. III.: Application. Illustrated. 12mo, cloth. $1.50.

SCHELLEN, H., Dr. Magneto-Electric and Dynamo-Electric Machines. Their Construction and Practical Application to Electric Lighting and the Transmission of Power. Translated from the Third German Edition by N. S. Keith and Percy Neymann, Ph.D. With very large Additions and Notes relating to American Machines, by N. S. Keith. Vol. I. With 353 Illustrations. Third Edition. $5.00.

SEVER, G. F. Electrical Engineering Experiments and Tests on Direct-Current Machinery. With Diagrams and Figures. 8vo, pamphlet. Illustrated. $1.00.

SEVER, G. F., and **TOWNSEND, F.** Laboratory and Factory Tests in Electrical Engineering. 8vo, cloth. Illustrated. In press.

SEWALL, C. H. Wireless Telegraphy. With Diagrams and Figures. Second Edition, corrected. 8vo, cloth. Illustrated. $2.00.

SHELDON, S., Ph.D., and MASON, H., B.S. Dynamo-Electric Machinery: Its Construction, Design, and Operation. Direct-Current Machines. Fourth Edition, revised. Illustrated. 8vo, cloth. Net, $2.50.

Alternating-Current Machines; being the second volume of the authors' "Dynamo-Electric Machinery: its Construction, Design, and Operation." With many Diagrams and Figures. (Binding uniform with Volume I.) Third Edition. Illustrated. 8vo, cloth. Net, $2.50.

SLOANE, T. O'CONOR, Prof. Standard Electrical Dictionary. 300 Illustrations. 8vo, cloth. $3.00.

SNELL, ALBION T. Electric Motive Power. The Transmission and Distribution of Electric Power by Continuous and Alternate Currents. With a Section on the Applications of Electricity to Mining Work. Illustrated. 8vo, cloth. $4.00.

SODDY, F. Radio-activity: An Elementary Treatise from the Standpoint of the Disintegration Theory. Fully Illustrated, and with a complete table of Contents and Extended Index. 8vo, cloth. In press.

SWINBURNE, JAS., and WORDINGHAM, C. H. The Measurement of Electric Currents. Electrical Measuring Instruments. Meters for Electrical Energy. Edited, with Preface, by T. Commerford Martin. Folding Plate and numerous Illustrations. 16mo, cloth. 50 cents.

SWOOPE, C. WALTON. Practical Lessons in Electricity: Principles, Experiments, and Arithmetical Problems. An Elementary Text-book. With numerous Tables, Formulæ, and two large Instruction Plates. Fifth Edition. Illustrated. 8vo, cloth. Net, $2.00.

THOM, C., and JONES, W. H. Telegraphic Connections, embracing recent methods in Quadruplex Telegraphy. 20 Colored Plates. 8vo, cloth. $1.50.

THOMPSON, S. P., Prof. Dynamo-Electric Machinery. With an Introduction and Notes by Frank L. Pope and H. R. Butler. Fully Illustrated. (No. 66 Van Nostrand's Science Series.) 50 cents.

Recent Progress in Dynamo-Electric Machines. Being a Supplement to "Dynamo-Electric Machinery." Illustrated. 12mo, cloth. (No. 75 Van Nostrand's Science Series.) 50 cents.

TREVERT, E. How to Build Dynamo-Electric Machinery. Embracing the Theory, Designing, and Construction of Dynamos and Motors. With Appendices on Field-Magnet and Armature Winding, Management of Dynamos and Motors, and useful Tables of Wire Gauges. Illustrated. 8vo, cloth. $2.50.

TUNZELMANN, G. W. de. Electricity in Modern Life. Illustrated. 12mo, cloth. $1.25.

UNDERHILL, C. R. The Electromagnet: Being a new and revised edition of "The Electromagnet," by Townsend Walcott, A. E. Kennelly, and Richard Varley. With Tables and Numerous Figures and Diagrams. 12mo, cloth. Illustrated. $1.50.

URQUHART, J. W. Dynamo Construction. A Practical Handbook for the use of Engineer Constructors and Electricians in Charge. Illustrated. 12mo, cloth. $3.00.

Electric Ship-Lighting. A Handbook on the Practical Fitting and Running of Ships' Electrical Plant, for the use of Ship Owners and Builders, Marine Electricians, and Sea-going Engineers in Charge. 88 Illustrations. 12mo, cloth. $3.00.

Electric-Light Fitting. A Handbook for Working Electrical Engineers, embodying Practical Notes on Installation Management. Second Edition, with additional chapters. With numerous Illustrations. 12mo, cloth. $2.00.

WADE, E. J. Secondary Batteries: Their Theory, Construction, and Use. With innumerable Diagrams and Figures. 8vo, cloth. Illustrated. Net, $4.00.

WALKER, FREDERICK. Practical Dynamo-Building for Amateurs. How to Wind for any Output. Illustrated. 16mo, cloth. (No. 98 Van Nostrand's Science Series.) 50 cents.

WALLING, B. T., Lieut.-Com. U.S.N., and MARTIN, JULIUS. Electrical Installations of the United States Navy. With many Diagrams and Engravings. In press.

WALMSLEY, R. M. The Electric Current. How Produced and How Used. With 379 Illustrations. 12mo, cloth. $2.50.

WEBB, H. L. A Practical Guide to the Testing of Insulated Wires and Cables. Illustrated. 12mo, cloth. $1.00.

WEYMOUTH, F. MARTEN. Drum Armatures and Commutators. (Theory and Practice.) A complete treatise on the theory and construction of drum-winding, and of commutators for closed-coil armatures, together with a full résumé of some of the principal points involved in their design; and an exposition of armature reactions and sparking. Illustrated. 8vo, cloth. $3.00.

WORMELL, R. Electricity in the Service of Man. A Popular and Practical Treatise on the Application of Electricity in Modern Life. From the German, and edited, with copious additions, by R. Wormell, and an Introduction by Prof. J. Perry. With nearly 850 Illustrations. 8vo, cloth. $5.00.

THIRD EDITION, REVISED.

Pocket Size, Flexible Leather, 1,000 Pages, with innumerable Diagrams, Illustrations and Tables. PRICE, $5.00.

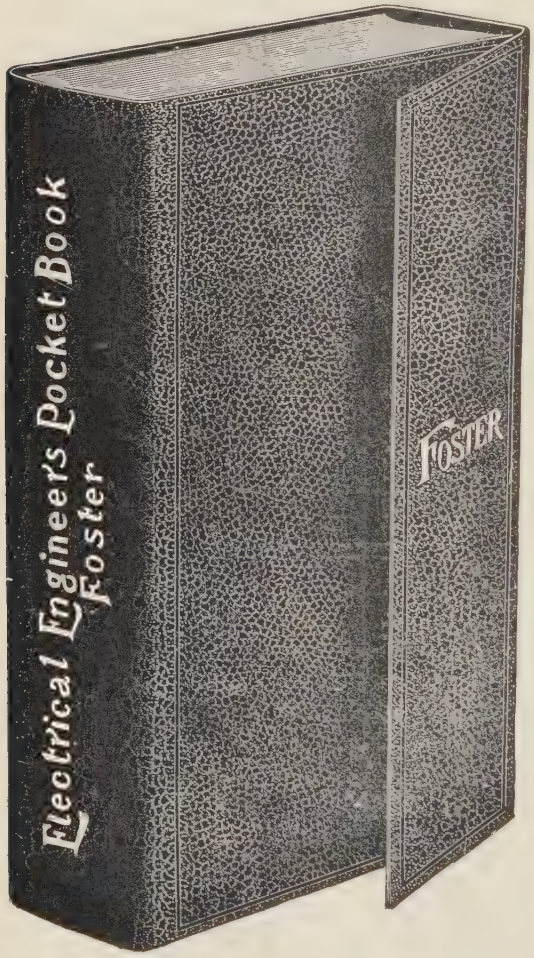
ELECTRICAL ENGINEER'S POCKETBOOK

The Most Complete Book of its kind ever Published, Treating of the Latest and Best Practice in Electrical Engineering,

By HORATIO A. FOSTER,

Member Amer. Inst. E. E., Member Amer. Soc. M. E.

(WITH THE COLLABORATION OF EMINENT SPECIALISTS.)



⅔ actual size.

CONTENTS.

Electrical Engineering Symbols. Electrical Engineering Units. Description of Instruments. Resistance Measurement. Measurement of E.M.F. Measurement of Capacity Measurement of Inductance. Measurement of Power on Alternating Current Circuits. Tests with Voltmeter. Determination of Magnetic Properties of Iron and Steel. Determination of Wave Form of E. M. F. and Current. Conductors, Properties of. Conductors, Relation and Dimensions of, for Transmission of Electric Current. Transmission of Power. Switchboards and Switching Devices. Cable Testing. Electromagnets. Dynamos. Motors. Testing Dynamos and Motors. Static Transformers. Electric Lighting. Electric Railways. Storage Batteries. Telegraph. Telephone. Electro-Chemistry. Electro-Metallurgy. Electric Heating, Welding and Cooking. Electricity Meters. Lightning Arresters. Lightning Conductors. National Code Rules and Requirements. Miscellaneous Electrical Data. Certain Uses of Electricity in U.S. Army and Navy. Mechanical Section. Index.

D. VAN NOSTRAND COMPANY, PUBLISHERS AND BOOKSELLERS,

23 MURRAY and 27 WARREN STS., NEW YORK.

***Copies sent prepaid on receipt of price.

FIFTH EDITION.

8vo., Cloth. 385 Illustrations. 462 Pages. - Price, 2.00 Net.

LESSONS IN

PRACTICAL ELECTRICITY

PRINCIPLES, EXPERIMENTS, AND ARITHMETICAL PROBLEMS.

AN ELEMENTARY TEXT BOOK

With Numerous Tables, Formulæ, and Two Large Instruction Plates.

BY

C. WALTON SWOOPE

Associate Member American Institute of Electrical Engineers,
Instructor of Applied Electricity at the Spring
Garden Institute, Philadelphia.

Five years ago the author prepared a private edition of "Lessons in Practical Electricity," which was published by the Spring Garden Institute for the use of its evening classes in practical electricity.

The demand for the book arose from two facts: First—these classes, being composed of young men engaged in various occupations who desired to obtain a beginner's knowledge of the principles and arithmetic of applied electricity, were very large; Second—an unsuccessful attempt was made to obtain a book suitable for thoroughly supplementing a combined course of lectures and individual laboratory work.

The educational success attained at the Institute, and also at several other schools which secured the privilege of obtaining copies of the edition (now exhausted), and the fact that the former situation had again to be met, seemed to warrant the preparation of the present volume, which has been entirely re-written and several hundred new illustrations introduced.

An attempt has been made to combine in this book: (1) the principles of electricity upon which the practical applications of to-day depend; (2) the experimental demonstration of these principles; (3) the elements of the arithmetic of electricity used in making practical electrical measurements and calculations.

Illustrations have been generously introduced to make the principles clear, in preference to pictures of electrical machinery in common use, these being supplemented by numbered experiments, which may be conducted with simple and inexpensive, yet efficient, apparatus such as that described, which was designed for, and is now used by the Institute.

A knowledge of fractions, decimals and simple proportion will enable the student to make nearly all the calculations.—*Preface.*

CONTENTS.

Lesson I.–Magnetism. II.–Magnetisation. III. Magnetic Fields. IV.–Theory of Magnetism. V.–Magnetic Induction. VI.–Magnetic Circuits. VII.–Earth's Magnetism. VIII.–Voltaic Electricity. IX.–Batteries. X.–Electrolysis. XI.–Measurement of Current Strength. XII.–Resistance. XIII.–Ohm's Law and Battery Connections. XIV. Circuits and Their Resistance. XV.–Electromagnetism. XVI.–Galvanometers. XVII.–Electromagnets. XVIII.–Ammeters. XIX.–Electrical Work and Power. XX. Measurement of Pressure. XXI.–Measurement of Resistance. XXII.–Electrical Development of Heat. XXIII.–Electrodynamics. XXIV.–Electromagnetic Induction. XXV.–The Induction Coil. XXVI. Dynamo-Electric Machines. XXVII.–Armatures. XXVIII. Direct Current Dynamos. XXIX.–Direct Current Motors. XXX.–Electric Lighting. Appendix. Index.

D. VAN NOSTRAND COMPANY.

Publishers and Booksellers,

23 MURRAY AND 27 WARREN STREETS, NEW YORK.

Copies sent prepaid on receipt of price.

Just Published

12mo. Cloth, Illustrated, 127 pp. - - Price, $1.00.

The How and Why of Electricity

BY

CHARLES TRIPLER CHILD,

Late Technical Editor of the "Electrical Review."

CONTENTS.

Preface. The Electric Current, The Electric Battery. The Effects of Electric Flow in the Circuit—Heat and Chemical Action. The Effects of Electric Flow Outside the Circuit—Magnetism and Induction—The Electrical Units. Electromagnets—The Telegraph. Electric Signaling Apparatus. The Relations Between Magnets and Electric Currents. Induction and Reactive Coils. The Telephone. Telephone Accessories. The Mechanical Generation of Electricity. The Dynamo Machine. Various Types of Dynamo Machines. Alternators —Polyphase Currents. The Electric Motor. The Electric Railway. Polyphase Currents and Motors. Electrical Power Transmission. The Incandescent Light. The Arc Light. Electrochemistry—Storage Batteries. Wireless Telegraphy. Radiation—X-Rays.

"Is admirably adapted to instruct the non-technical reader who is interested in that subjec * * * Mr. Child enjoyed a high reputation for the clearness and intelligibility of his writing, and the volume in question exhibits these qualities."—*New York Tribune, December* 26, 1902.

"In spite of the great mass of electrical literature already existing, it is one of the first good books of its kind. * * * It will find a large circle of readers on its evident merits."—*Engineering News, New York, February* 19, 1903.

"Mr. Child has left a good book ; one that we can heartily commend to the non-technical readers for whom it was written ; they will not be led astray by platitudinous nonsense, but will receive solid, exact information if simply expressed." - *Western Electrician, Chicago, February* 21, 1903.

D. VAN NOSTRAND COMPANY,

Publishers and Booksellers,

23 MURRAY AND 27 WARREN STREETS, NEW YORK.

Copies sent prepaid on receipt of price.

JUST ISSUED.

8Vo. Cloth, Illustrated, 200 Pages, . . Price, $4.00 Net.

PRACTICAL X RAY WORK

WITH TWELVE PLATES FROM PHOTOGRAPHS OF X RAY WORK,

—BY—

FRANK T. ADDYMAN,

B.Sc. (Lond.), F.I.C.

CONTENTS.

PART I.—**HISTORICAL.**

CHAP. I. Introduction. CHAP. II. Work Leading Up to the Discovery of the X Rays. CHAP. III. The Discovery.

PART II.—**APPARATUS AND ITS MANAGEMENT.**

CHAP. I. Electrical Terms. CHAP. II. Sources of Electricity. CHAP. III. Induction Coils. CHAP. IV. Electro-static Machines. CHAP. V. Tubes. CHAP. VI. Air Pumps. CHAP. VII. Tube-holders and Stereoscopic Apparatus. CHAP. VIII. Fluorescent Screens.

PART III.—**PRACTICAL X RAY WORK.**

CHAP. I. Installations. CHAP. II. Radioscopy. CHAP. III. Radiography. CHAP. IV. X Rays in Dentistry. CHAP. V. X Rays in Chemistry. CHAP. VI. X Rays in War. Index.

LIST OF PLATES.

FRONTISPIECE—Congenital Dislocation of Hip-joint. I. Needle in Finger. II. Needle in Foot. III. Revolver Bullet in Calf and Leg. IV. A Method of Localization. V. Stellate Fracture of Patella showing Shadow of "Strapping." VI. Sarcoma. VII. Six-weeks'-old Injury to Elbow showing New Growth of Bone. VIII. Old Fracture of Tibia and Fibula Badly Set. IX. Heart Shadow. X. Fractured Femur showing Grain of Splint. XI. Barrell's Method of Localization.

D. VAN NOSTRAND COMPANY,

Publishers and Booksellers,

23 Murray and 27 Warren Sts., NEW YORK.

***Copies sent prepaid on receipt of price.

WILLIAM J. HAMMER,
CONSULTING ELECTRICAL ENGINEER,
1406 HAVEMEYER BUILDING,
26 CORTLANDT ST., NEW YORK.
TELEPHONE, 251 CORTLANDT.

Time
Aug 9 '37
Pop Mech.
Dec. 38

546.42 H224

a39001 007010930b

546.42
224

1329
66-1